WAR DEPARTMENT

CHEMICAL WARFARE SERVICE

RESEARCH DIVISION

AMERICAN UNIVERSITY EXPERIMENT STATION

WASHINGTON, D. C.

MAJOR GENERAL W. L. SIBERT, DIRECTOR

COLONEL G. A. BURRELL, CHIEF OF RESEARCH DIVISION

CHEMICAL DEVELOPMENT SECTION

W. K. LEWIS, IN CHARGE

SUMMARY OF ACHIEVEMENTS

1917 - 1918.

CHEMICAL DEVELOPMENT SECTION

The Chemical Development Section of the Research Division is an outgrowth of the Manufacturing Development Division formed under the leadership of Dr. W. K. Lewis, a pioneer member of the early Bureau of Mines organization for War Gas Investigations. The original Manufacturing Development Division worked on chemical and mechanical research and development problems. Later it contained an organization known as the Emergency Squad. This squad was formed with Mr. R. G. Knowland as its leader at time when it was necessary to have a group of men who could quickly turn their attention to any problems of especial importance with a view to obtaining a speedy and accurate solution. Consequently, their work was done largely in conjunction with that of other divisions.

In many of the problems originating at the American University Experiment Station, it was necessary to investigate and often secure large quantities of chemicals not in general use, or to locate some special piece of apparatus. This work, together with rush chemical testing, was done by the emergency unit. A large number of special analyses and tests were made when men were not available in other laboratories, and, in fact, the work of these men

varied from messenger service to the study of little known and extremely poisonous gases.

In connection with many development possibilities, this unit did work of great value in securing the prices, location, and availability of necessary supplies. In peace times, such investigations would have been comparatively simple, but under war restrictions and existing war industries' regulations, the work was at times very difficult.

Shortly after the formation of the Emergency Squad, the mechanical research and development work, which had been entirely in the hands of Mr. H. H. Clark, was so divided that Mr. Clark continued with a certain portion of the work, while the liaison service between the Bureau of Mines and the Gas Defense Service was furnished by a unit under the direction of Mr. B. B. Fogler. At a later date, all the mechanical research and development work was placed in charge of Mr. B. B. Fogler, directing the Mechanical Research and Development Division.

Some time later the work of the Emergency Squad and also the chemical research and development work of the Manufacturing Development Division were brought together in the Chemical Development Section of the Research Division of the Chemical Warfare Service. This section was under the leadership of Capt. R. G. Knowland, and afterward, under Lieut. Allen Abrams. The organization continued

work on emergency problems, and assisted other sections in the development of chemical processes which were to be put on a manufacturing basis.

The following report gives a brief account of the problems with which this section has been concerned. The discussion is presented by subjects rather than chronological order.

CHARCOAL

NEW SOURCES OF CHARCOAL: In November, 1917, the National Carbon Company had developed the first semi-commercial charcoal steam activating unit, and required the services of more men than they could supply. Consequently, this section supplied two men, one of whom remained permanently at that station. These men continued the work on this furnace until definite recommendations were made to Mr. Dorsey, who was developing the large commercial unit.

This small unit consisted of a 7" clay saggar, approximately 2' long, provided with a hopper feed and slide discharge. This sagger was surrounded by a resistor carbon electric furnace, enclosed in a large clay cylinder. The entire furnace was packed in silocel and surrounded by a brick wall. The steam was admitted through a 1/4" iron pipe running up from the bottom and terminating in

the middle of the furnace. This furnace was continuous in action, providing for the admission of raw coal at the top, its passage down into the hot zone at about 900°C, treatment with steam and the resulting activation, and finally cooling in the lower part of the furnace and discharging as a finished product at the bottom.

OPERATION AND CONTROL OF THE DORSITE CHARCOAL HEATERS AT ASTORIA, L.I. At the time of the investigation covering the month of April, 1918, there were ten steam treaters in operation at the plant of the Astoria Light, Heat & Power Company.

The main difficulties encountered in the operation of these furnaces were as follows: Irregularity in quality of the treated charcoal; rapid burning out of the nichrome heater tubes, necessitating long and frequent shut-downs of the furnaces; and ineffective temperature control in the heater tube.

Complete investigations were made of the operation and control of the two methods of heating then in use, - the swirling flame and the surface combustion. For this purpose two furnaces, one of each type, were used as experimental furnaces, and an exhaustive study made of their relative merits. A study of the data obtained in these tests resulted in the adoption of a new method of temperature control. The following conclusions relative to the

operation of the furnace were also indicated: Irregularity of quality can be due to temperature fluctuation at the reactive zone of the furnace; rapid passage through the reactive zone, due to steam pocketing or breaking up of a cake; and steam condensation on the treated charcoal after treatment.

Temperature charts which were plotted from data, obtained from thermo couples inserted in the walls of the furnace, indicated that the best method of temperature control was by means of a couple inserted at the reactive zone and against the nichrome tube. The best location for the control couple in the furnace was located by a series of tests on the temperature gradient along the tube. Data from these tests furnished a basis for the comparison of the two types of furnaces, and indicated that surface combustion design gave the best temperature control.

STRUCTURE OF CHARCOAL: In spite of the fact that so much work has been devoted to the development of high absorption charcoal for gases, there is practically nothing known concerning the manner in which the structure changes with increase in absorption value. If this were known, it might suggest the way in which this structure could be duplicated in manufacture. This was particularly important since the problem of reproducing the German charcoal had been turned over to the Research Division.

The only method available seemed to be the study of the amount of readily condensible gas absorbed at different equilibrium pressures of the gas. From the shape of the curve obtained on plotting this data, it would be possible to calculate the size of the pores by a formula based on thermodynamic considerations.

The necessary apparatus for this investigation was assembled and measurements were made. The apparatus was complicated and required careful operation to obtain the required precision. A great amount of care was expended in obtaining charcoal absolutely free from foreign gases, since it was believed that this point had never received the proper attention, and that previous work had involved the absorption of the gas in question, not on a pure carbon surface, but on a surface upon which air, water, etc., had already been absorbed.

It was planned to make a study of a series of our own charcoals between 0 and 60 min. (accel. chloropicrin test) in order to ascertain the nature of any systematic variations, and also to study other representative charcoals, such as the German, English, and French materials.

This problem was under consideration when the war ended. The persons en gaged in this investigation were: C. K. Reiman, J. B. Dickson, and H. M. Cyr.

PRODUCTION OF BATCHITE: The use of poisonous gases in the war made the perfection of suitable protective devices imperative, and this was particularly true in the case of charcoal. Cocoanut shell calcined, ground, and treated at a temperature of from 850°C-950°C with superheated steam produced a satisfactory absorbent, but the limited amount of shell available made a secondary source of charcoal advisable.

The laboratory of the National Carbon Company determined the experimental conditions for the activation of anthracite. A unit of the Chemical Development Section, under the direction of H. S. Wilkins, was organized to develop the method. The first trial, using a Glover-West vertical, continuous-feed retort, was not successful, but the second trial, using intermittent, inclined retorts, gave quite satisfactory results. The following schedule produced the best material:

Time of treatment	48 hours.
Charge	2000 lbs.
Size green coal charged	8-14 standard mesh
Temperature	900° to 950°C
Steam	100 lbs. per hour

This charcoal averaged 15 minutes on the accelerated chloropicrin test. The loss of weight in treatment varied from 25% to 33%, depending upon the degree of activation obtained. Steam was run through hot coal only, since the water gas reaction ($C + H_2O = H_2 + CO$) does not take

place, appreciably, below a temperature of 850°C. This reaction plays the chief part in the activation, and has a distinct cooling effect, so that if steam were run continuously, the proper temperature would not be maintained. The retort temperature was determined by the appearance of the flame formed at the upper door by the combustion of reaction products. The limited capacity of the producers prevented excessively high temperatures, and, although as carful control as possible was maintained, the product was rarely uniform. The average, passing a 12 min. standard, was about 75%.

As the demand for charcoal became greater, the supply of cocoanut proved to be insufficient, and the Batchite Plant at the Springfield Gas Light Company went from a development to a production basis. Beginning about July 1, 1918, nearly 5 tons a day were produced. This output was increased rapidly until a 10 ton minimum was passed, with a maximum production of over 15 tons in a single day.

Shortly after production was begun, the Gas Defense Division assumed control of the plant, and the work was continued by them until the end of the war.

AIR DENSITY OF BATCHITE: One of the most desirable materials for the gas mask absorbent was a charcoal made from nut shells and fruit pits. The supply of these materials

being limited, it was found necessary to look for substitutes. Anthracite coal, when subjected to a certain heat treatment, had been found to yield a product with an average absorption capacity somewhat less than that made from nut shells. This material is technically known as Batchite.

A close examination of a sample of average batchite shows that the individual particles have densities within the limits of 1.20 to 1.60. The less dense particles have a greater absorbing power for toxic gases than the heavier ones, and it was therefore proposed to apply air separation to the mixture. All the factors governing this separation were thoroughly studied.

For this purpose, a machine was developed in which the batchite was introduced into the lower portion of a vertical tube, through which tube a blast of air was blowing. The air velocity was so regulated that the lighter particles were blown out at the top of the tube into one compartment while the heavier particles dropped out at the bottom into another. By this means, average batchite was separated into two portions, the lighter of which had an absorbing power much greater than the original material.

STEAM DISTILLATION OF CRUDE COCOANUT: In December, 1917, Capt. Woodruff and Mr. Dorsey desired to try the steam distillation of ground cocoanut in the horizontal retorts at Astoria. This section sent a man there to carry out this

work with the assistance of the Gas Defense Service. It was first necessary to equip the retorts with some means of steam distribution, as they were the ordinary D-shaped horizontal gas retorts. This was done by making a false bottom of channel irons, perforated with 1/8" holes, under which perforated steam pipes were run. The steam used was measured by an orifice.

As the retorts were maintained at approximately 900°C. the steam at that temperature had a very destructive oxidizing action on the iron channels and pipes. After 24 hours running, a half inch wrought iron pipe showed incrustations of iron oxide 1/8" thick, both inside and outside, plugging up most of the holes. The same was true of the channel irons which also bent and buckled in the middle under the weight of the charge. It was determined that this method of introducing steam was impractical, as the life of the iron work was so short, and it was impossible to maintain open holes for even distribution of the steam. This rapid oxidation of the iron was slightly less acute on the surface of the channel iron exposed to the carbon, but the under side of the channels and the steam pipes were in perfect condition for oxidation, - temperature of 900°C and an atmosphere of superheated steam.

In spite of the short life of the steam distributing system, it was clearly shown that the carbonizing

time could be cut down from 12 hours to 8 hours with better results. Furthermore, the material so distilled had an activity of from 0 to 4 minutes (accelerated chloropicrin test), while without the steam treatment, the material had no or even a "negative" activity (i.e. was not completely carbonized). This process produced better material for the main activation process in the Air or Dorsite Treaters. About 500 lbs. was determined to be the best charge per retort. Work was then started to design improved methods of introducing the steam, which work was continued by the Gas Defense Division.

The results of this work were: The introduction of over one hundred retorts equipped with a perforated fire-clay, falsebottom; an increased production in these retorts due to the decrease in time of carbonization, and furthermore, this advance in design made possible the utilization of these retorts for the production of batchite when later introduced.

<u>DORSEY STEAM TREATERS</u>: Twice, when difficulty had been experienced in operating the Dorsey Steam Treaters at Astoria, a man was furnished from this section to assist in determining the cause for and remedying such difficulty.

The most serious trouble was the irregular quality of the product. This was traced to large fluctuations in temperature, which were the result of two causes. First.

the formation of "gas pockets", causing the pyrometer in that tube to show a marked increase in temperature, due to the fact that it was in a pocket of gas and no longer imbedded in the charcoal where an enthothermic reaction was taking place. Secondly, because of this increase in temperature, the burner men cut down the gas fired to that retort, and consequently when the effect of the decreased heat supplied was felt, the gas pocket had broken and the material had dropped to a low temperature. The gas supply was again increased, and the temperature raised. This method of operation gave a very irregular temperature control, and as the rate of passage of the material through the furnace was constant, the quality varied with the different treatment given to it. By insisting that tha gas supply be changed only as a last resort to prevent burning out of the tube, and breaking the pockets as soon as formed, it was possible to get a quite uniform temperature and an improved product.

Work was also done collecting miscellaneous data on the furnaces, such as temperature gradients, horizontally and vertically inside and outside of the nichrome tube, and determining the quality of the product under various conditions of temperature and rate of flow. Tubes were coated to varying heights with alundum cements, and provided with baffle walls of different heights. The work of the men from this section was not confined to one particular job, but

they studied related problems, such as gas analyses of the various products of combustion, etc. All of this work was of great value in the further developments of this type of furnace.

INTRODUCTION OF BATCHITE AT ASTORIA: When the production of batchite at Springfield, Mass., proved to be a success, it was decided to introduce its manufacture at Astoria, using horizontal retorts. Previous work had shown that a vertical type of furnace was unsatisfactory for treating and activating batchite, due to the "gas treating" of the material by the products of combustion. At Springfield, after finding the vertical retorts to be a failure, the inclined retorts were tried, using a thin layer of the coal over a perforated steam pipe. This was successful, so there was no reason why the horizontal steam-bottomed retorts at Astoria should not be even more satisfactory, since they would give a large area with a very shallow layer of material.

A few unsuccessful runs were made by the Astoria organization but with no results, the material testing under 5 minutes (accelerated chloropicrin). Lieut. Holton of this section, who had had experience, was then sent out to put the thing on a production basis. First, a series of runs were made on four retorts in order to determine the best operating conditions for this type of furnace. It was found

that: (1) About 1000 lbs. of raw coal was the best charge to use; (2) the temperature must be maintained above 850°C for good results; (3) the time should be at least 36 hours, and for the best results, 48 hours; (4) the maintenance of a sufficient and uniform distribution of steam was essential; (5) due to the leaks in the ends of the false bottoms, much more steam had to be used in the retort than was needed to activate the coal (about 250 lbs. of steam per hour were used per 1000 lb. charge); (6) it was necessary to keep the material well stirred. With these points in mind, new retorts were started as soon as equipped with suitable steam orifices for measuring the steam flow. It soon became evident that the majority of the retorts were in such poor condition that only a small proportion - 20% or so - of the steam actually reached the coal. With good retorts, the material would average 15 to 20 minutes (accelerated chloropicrin test) with some runs as high as 27 minutes, while with poor retorts the test would run anywhere from one minute to 10 or 12 minutes. Before long, 40 or 50 retorts were in operation turning out about 10 tons of material a day, of which only 30% to 50% was passable. After a change of organization in which special men were put in charge of keeping the retorts patched up and in good condition, the amount of passable material was raised to 70%.

The different stages of the process were as follows: The raw coal, received at the dock, was ground at a special

grinding plant and screened 6-14 mesh, bagged or drummed, and sent to the retort house. There it was loaded by hand, either directly with the retorts or else by the charging scoops. When charged, it was levelled off to give a four inch layer, and stirred every hour for 48 hours. The steam was kept on at all times, unless the temperature fell below 800°C, when it was shut off until the temperature again reached 850°C. The discharge was run directly into a steel drum or car, and allowed to cool, and later drummed and sampled. The product was then finished and ready for shipment. On large scale production, it was impossible to get an average passable material of over 15 min. (accelerated chloropicrin test). The entire batchite program was to build up a reserve supply in case of emergency. As a reserve, batchite, and its process, stands as a valuable asset, since it furnishes a quick and ready source of suitable medium quality absorbent.

The use of the horizontal retorts for the production of batchite at the Gas Defense plant, Astoria, L.I., provided a source of charcoal at a time when the supply of nut shells had fallen to a minimum. Most of the sources of cocoanut shell were beyond the limits of the United States and our supply was dependent upon water transportation. The shipping of the country was taxed to the limit, the shells were bulky and a loss of nearly 80% occurred during the treatment, making it very difficult to meet the demand

for shell charcoal. To secure a supply of absorbent charcoal from a material as available as anthracite coal proved to be a great help at this critical period. The batchite produced was used to meet the demands of the British as well as our own government.

Mr. Bridgewater of this section aided Mr. Holton in the supervision of the work.

DEVELOPMENT OF THE EXTERNALLY FIRED ROTARY FURNACE: Lieut. J. Holton, of this section, was detailed to the Gas Defense Division at Astoria to develop an externally fired rotary furnace. It was suggested that a rotary furnace could be used to activate charcoals. Such a furnace would produce a uniform product, and be continuous in action.

The first step was to obtain the use of No. 2 American Gas Furnace containing a rotating tube 7½" inside diameter and about 4 ft. long. This was used with intermittent charges and provided with various possible types of steam jets and distributing systems. In this furnace, it was possible to activate cocoanut charcoal to 30 min. or more in about an hour. This work proved so promising that a commerical size unit was designed. Against considerable opposition, the representative from this section insisted that the steam be admitted under the charcoal and thus pass up and out, driving out the waste gases instead of merely

playing over the surface of the charge. This was later proven to be an essential consideration in producing the highest quality of material.

All details were soon drawn up and construction started. The base of the furnace rested on a steel cradle made of I beams resting on two concrete supports 10 feet apart, the cradle being hinged on one support, thus allowing the slope of the furnace to be varied as desired. At either end of the cradle, there were two rollers, supporting two heavy tires attached to the large rotary tube. This tube was a nichrome casting, 13 ft. 6 in. long and 15 in. inside diameter with about 11 feet span between tires. Fastened to this tube was a sprocket chain driven from a worm and gear which in turn took its power from the main line shaft. In order to secure continuous rotation of the tube at all times, a separate electric drive was provided to be immediately shifted into use when the main power failed, besides a hand crank attached directly to the worm and gear. In this way there was but little chance for the tube remaining stationary while hot, and thus sag or get out of true. Around this tube was built the fire brick combustion chamber arched over at the top, and gas fired from rows of jets at either side, which were fed from four Premix Burners. It was found necessary, to conserve heat, to further lag the outside of the furnace with asbestos boiler covering. Sufficient insulating brick was not used due to the excessive

weight, which would have been put upon the cradle. The ends of the tube were provided with charging and discharging devices, which, while somewhat clumsy, were successful in operation and prevented the great delay caused by waiting for castings and parts to make the large glands which were to be used in the final layout. The charging device consisted of a hopper fastened to and rotating with the tube, which permitted itself to be charged, while vertical during one revolution and then during the next revolution it discharged into the furnace. The discharge device worked similarly, but in the reverse order. The steam distributing device consisted of a two inch nichrome tube running the full length through the axis of the tube, enlarged at one end to 4 inches and provided with an opening to allow the waste gases to pass out. At three inch intervals along the two inch diameter section, half inch jets were provided, extending within one inch of the wall of the tube, and perforated at the ends. A steam superheater was also designed and built for this furnace with a capcity of 400 lbs. of steam per hour at 500°C. Thus the raw carbonized material was charged at one end, and discharged at the other, the total slope being 4 inches in 10 feet. While passing through the tube, it was heated to 950°-1000°C. and submitted to the action of steam at the same temperature. The constant rolling, tumbling, and mixing gave almost ideal

conditions for the activation of the material, and a capacity far exceeding the old stationary type of treaters was secured. After continued use, the steam tube sagged slightly allowing the jets to wear on the bottom of the tube and the perforations to clog up. However, cutting off the jets about $1\frac{1}{2}$ in. and leaving a $\frac{1}{4}$ in. open hole, gave just as good activation and insured better operation.

At this time the representative from this section was called away to other work, and so was unable to continue his experimentation, but the work was continued by others, with remarkable results. It was found possible to produce cocoanut charcoal testing 45 min. to 55 min. (accelerated chloropicrin) at the rate of 50 lbs. an hour. This was more than twice the production and three or four times the quality of the charcoal manufactured in the old stationary Dorsite Treaters. The uniformity of product is far greater than with the stationary type, due to the thorough tumbling and mixing. The development has continued improving many of the construction details and increasing production by increasing the heated zone, but maintaining the same high quality. This furnace stands to-day as the best activating furnace known, which has been tried out and proved successful.

<u>INTERNALLY FIRED ROTARY STEAM TREATER</u>: Lieut. Holton was called from the work in connection with the externally fired

rotary furnace to aid the testing and development of an internally fired rotary furnace.

Cement kilms at a cement plant in Egypt were secured by the government for this experimental work. Capt. Seaman and Lieut. Holten worked together in laying out an experimental schedule. The rate of feed, steam rate, operating temperature, and heating system were given careful attention. After a systematic investigation of the variables, a schedule that gave good results with cocoanut shell was established. From Egypt, Lieut. Holten was sent to the Research Division at the National Carbon Company, Cleveland, Ohio. Here he was placed in charge of a detachment of men who were investigating new sources of activated charcoals and studying the process of activation. Mr. H. D. Batchelor of the National Carbon Company directed the research. Very satisfactory progress had been made, both in the production of high grade coals and in the study of the mechanism of the activation. This work was so promising that it was continued for some time after the war.

SMOKES

FELT SMOKE FILTERS: When the Germans began to use diphenylchloroarsine as an offensive smoke. it was evident that the American gas mask must be improved by the addition of a filter which would satisfactorily remove this and other irritating smokes. An investigation was commenced by Lieuts. Abrams and Spofford, working at the Mass. Institute of Technology, on a large number of materials, including woven cotton, woolen, and silk goods, and felted woolen goods; powdered metals, diatomaceous earth, powdered charcoal; blotting papers, "puffed" paper, impregnated papers; porous metal, earthen and alundum plates; and leathers of all kinds. The sulfuric acid method was used in testing these materials, both on smoke penetration and on clogging. After a large number of tests had been made, the following three substances seemed to offer the most promising field: leathers (particularly chamois skins), papers, and felts. It soon became obvious that leathers were unsuitable because of the variability in texture. Paper, in this stage of development, was fairly good, but felts seemed distinctly superior to any other material.

A series of experiments was now undertaken in connection with the American Felt Company and later with the Lowell Felt Company. These investigations covered a

large number of factors, such as the following: (a) Blending and treatment of wools; (b) effect on felts of manufacturing processes, including fulling, specking, and buffing; (c) shaping of felts for filters. As a result of these tests it was possible to outline a method by which felt for smoke filters could be satisfactorily made. Most of the leading felt manufacturers of the country were now called into conference, and, after sufficient preliminary trials, were able to produce felts which would meet the requirements for smoke filters.

At this point the mechanical arrangement of the filter was made the subject of an investigation. The internal wrapped canister, the flat plate filter, and the accordion filter were under consideration for a long time. From the beginning, however, the flat plate filter seemed to afford the most promising outlook, both on account of the simplicity of design and the security against leakage.

Large scale production of felt for smoke filters was undertaken by the Gas Defense Division after they had carefully surveyed the situation on wool procurement and on the capacity of the felt mills throughout the country.

Throughout the development period, and in the early stages of large scale production, this section erected and operated sulphuric acid testing machines. It is very largely due to this control work that felt was satisfactorily

produced for smoke filters.

INVESTIGATIONS OF SULPHURIC ACID SMOKE: When this section undertook the development of a smoke filter, it became necessary to formulate a method for testing filters. The research on such a smoke was begun by Lieuts. Abrams and Spofford in the laboratories of Mass. Institute of Technology, using SO_3 as the smoke-producing substance.

The quantitative absorption of smoke particles had not been worked out at that time, so that all of the testing had to be done either in a qualitative way or by the Tyndall-effect method.

A crude testing apparatus was installed wherein sulphuric acid smoke was generated by mixing measured amounts of humidified air and of dry air saturated with SO_3 vapor. The resultant smoke was passed into a chamber whence it could be breathed through smoke filters.

The demand for a quantitative method to use in measuring smoke concentrations and filter penetrations became so great that an exhaustive research was made to find a way of completely absorbing this, as well as other smokes. It was finally demonstrated that coarse alundum thimbles were admirably suited to all this work, since when smoke-filled air was bubbled through these thimbles, immersed in the proper solution, complete absorption of the smoke took place. A testing method was at once evolved whereby filters

could be exposed to a sulphuric acid smoke of definite concentration, and the amount of penetration could be quantitatively determined. The clogging action of sulphuric acid smoke was also used to measure the quality of a filter.

A great part of the development work on felt and paper filters is due to the evolution of the sulphuric acid testing method. In view of the fact that this method was to be widely used in factory testing of felts, it became advisable to make a thorough study of all the factors and to establish a uniform method both of producing the smoke and of testing with the smoke. A portion of this work was done by the original authors of the test, but most of the experimentation was carried out by Lieut. Stevenson and Capt. Dickson. This research resulted in the production of a standard machine for producing sulphuric acid smoke, and of a standard method for testing against this smoke.

Lack of uniformity in smoke filters made it desirable to distinguish the weak spots. Lieut. Stevenson perfected a test wherein congo red paper was placed next the filters, and any sulphuric acid which penetrated the filter was registered on this paper. It was therefore not only easy to locate weak spots in the filter, but it was possible to distinguish between good and poor filters.

<u>"SUCKED ON" PAPER FILTER</u>: Upon the introduction of smoke as an offensive instrument by the Germans, a search for a

filter was begun. The work was divided into two fields: (1) The investigation of cellulose fibers, and (2) the investigation of wool fibers. While a few very promising paper filters had been developed none met all the specifications, - protection at low resistance, reproducibility, adaptability to large scale production, and capability to stand up under field conditions. The most promising cellulose fiber filter (the "sucked-on" filter) was develeped by this section and the Mechanical Research and Development Section at the A. D. Little Company, Cambridge, Mass. This filter, made into the shape of the 1919 canister, and of a size to fit over the war-gas container, was prepared by sucking cotton-seed hull fiber from a water suspension onto a wire frame of the required size and shape.

The first task in the development of this type of filter was to determine the optimum conditions of beating the raw cotton-seed hull fiber, the optimum weight per unit area, and the density. An exhaustive investigation was carried on with a special experimental filter, which permitted an individual study of each of the above factors.

Having determined the physical constants for the filters, the problem of machine control was taken up. Here the chief difficulty was to secure a sufficiently high density in packing the fibers. It was found that the factors which control density are consistency of stock (which determines also the time of forming), immersion of filter, and

speed of rotation. By correct adjustment, it was possible to just realize the minimum density, but to further increase the density, it became necessary to press the filter in a rubber bag, under a pressure of 25 lbs. per sq. in.

The problem of drying the filter was thoroughly studied, and the results indicated that the temperature of drying was immaterial, but that it was necessary to dry the filter in a rigid form to prevent distortions due to shrinkage (which amounts to about 4%).

The matter of forming the filter with or without a wire support was solved in favor of the latter method.

Under the proper conditions, filters were made which showed an efficiency of 96.5% against tobacco smoke (85 liter rate), a penetration of less than 5 p.p.m. by sulfuric acid smoke (32 liter rate), and a resistance of between 1 and 1.2 inches water. The average life of such filters on diphenylchloroarsine man test was 30 minutes.

THEORY OF SMOKE FILTRATION: A great amount of empirical work had been done on filters which promised to continue indefinitely unless some attempt was made to get at the fundamental principles underlying the process of smoke filtration. If a satisfactory theory covering these principles could have been obtained, it was evident that a great advance could be made because the most promising fields could be selected and completely investigated.

As a preliminary to the experimental work, the theories already advanced were critically examined, and on the basis on known facts, a tentative theory developed which were subjected to experimental tests. This theory assumed that: (1) The flow of smokes through filters was viscous flow; (2) the smoke particles reached the walls of the capillaries through the filter in virtue of their Brownian motion (diffusion); and (3) after striking the wall the particles were held or absorbed by the material of the wall. It seemed likely that there would be in addition some true filtering or sieving action on the larger particles.

With regard to (1), this section had shown that the flow through felt filters was viscous up to extremely high rates. With regard to (2), this section, in collaboration with Major Tolman's section, engaged on a study of the standard sulfuric acid smoke, whereby it was expected to discover the laws governing the diffusion of sulfuric acid smoke particles, their relative sizes, charge, etc.

Filters of known structure (for example, multipe cappillaries) were investigated to see whether the filtration obeyed the laws found by an examination of the smoke itself. With regard to (3), an investigation of the effect of changing the nature of the wall, meanwhile preserving the same structure, had progressed far enough to conclude

that the nature of the surface had a marked influence on qualities. In this experiment, the filter consisted of a tower filled with shot which were drenched with different liquids and through which sulfuric acid smoke was passed.

At the completion of this systematic investigation, it would probably have been possible to predict the kind of structure best adapted for filtering, and to suggest the best kind of fiber for "absorbing" a given smoke.

The persons engaged on this problem: J.B.Dickson, E.P. Stevenson, H.C. Weber, and E.R. Bridgewater.

MUSTARD GAS

MUSTARD GAS CLOTHING: When the vesicant properties and persistence of mustard gas were fully appreciated, it was decided that fabrics must be developed which would afford protection for the entire body. Before this work could be done, it was necessary to develop a chemical method for testing the time of mustard gas penetration of such fabrics. After considerable experimentation, it was found that when mustard gas was passed through an electric furnace to a high temperature, the gas was decomposed with the formation of SO_2. The SO_2 was then passed through a measured amount of standard iodine solution until decolorization took place.

The handling of mustard gas had caused so many serious burns that it became necessary to make impermeable gloves. Various impregnations were tried with the result that some gloves were treated with the boiled linseed oil, while others were impregnated with nitro-cellulose and rubber compounds. All of these treated materials were impermeable to air.

Suits of a similar impermeable fabric were made up and were given man tests to determine the comfort. It was found that such suits gave excellent protection against mustard gas, but were unbearable when worn for any considerabl

time, particularly in warm weather. The development was therefore begun of a more open fabric which would permit the passage of air and water vapor, but which would stop mustard gas. This led to investigations on fabrics which resulted in the adoption of a coarse, heavy, cotton cloth, known as Canaburg. It then became necessary to secure a suitable solvent for the mustard gas, and after about 200 tests had been made, a mixture of rosin oil, rosin, and paraffin oil was finally adopted.

MUSTARD GAS SUITS: Research on rapid solvents for mustard gas vapor in connection with the horse mask resulted in the conception and design of the overall fighting suit, largely under the direction of E.G. and T.M. Knowland. Previous to this, work had been done in other laboratories along the lines of protective underwear, but this material was open to the objection that the men had to wear contaminated clothing into the dugouts, with subsequent injury to others.

The simplexene suit was built with an inside layer of dry cloth together with an outside layer of treated cloth to afford the necessary chemical protection against mustard gas. Work of fabrication consisted in treating the cloth with simplexene, cutting the suits to design and size, and sewing them together. The cloth was treated at the Fabrikoid Works of the DuPont Plant at Newburgh, N.Y.

SILPLEXENE FIGHTING SUIT

SIMPLEXENE FIGHTING SUIT

Treatment consisted in passing the fabric through a dye machine, then through the wringer rolls where the excess oil was expressed. The inner layer of dry cloth was found necessary, since the cloth was cut as soon as treated. Simplexene does not attain the maximum degree of tackiness for two or three days, owing to the presence in the oil of a small amount of volatile spirits. However, by allowing the cloth to air for 48 hours before cutting, the inner lining could probably be dispensed with. The suits were designed in sizes to correspond to the overall sizes 36, 40, and 44.

The fighting suits have been distributed among various detachments using mustard gas in field tests, and in other places where protection against vapor is needed and where field conditions are approximated. These tests have shown that the suit gave satisfactory protection for considerable periods against mustard gas vapors. No other suit, equal both in porosity and protection, has yet been submitted, although samples furnishing better protection with much higher resistance have been examined. The protection of the simplexene suit is about 30 minutes against saturated gas. A large number of these suits was made and taken abroad for field tests at the front.

PRODUCTION OF HOOF PACKING RESISTANT TO MUSTARD GAS: This investigation was undertaken by Lieut. T. M. Knowland in

an effort to produce a satisfactory packing material for filling up the space left open at the back of a horse's hoof after the mustard boot is strapped into position. For such packing, a material of very special physical and chemical characteristics is needed, and research was therefore directed toward the development of a cheap substitute for the old tar-oakum packing.

A satisfactory packing has been developed with the following properties: It is plastic, capable of being easily rammed into position, and is easily scraped off when the boot is removed. The packing adheres firmly to the surfaces so that the plug cannot easily tear loose while the horse is working on rough or muddy ground. The packing has little tendency to flow or ooze after being rammed into position. It is not water soluble, and the viscosity is so great that in the event of contact with mustard gas, the rate of diffusion from the exposed surfaces upward toward the sensitive part of the hoof is negligible.

The material consists of equal parts of rosin and rosin oil with sufficient asbestos wool to give the proper viscosity. This mixture is distinctly pliable at $0^{o}C$, but it is not too soft at comparatively high temperatures such as might be expected in ground exposed to the sun. The stiffness of the packing is determined by the percentage of asbestos wool, and it is possible to attain a high viscosity without altering the adhesive properties

of the mixture. Use of the packing obviates the difficulties experienced with the old tar packing which softened so greatly in the sun that the dissolved mustard gas was at once carried up into the cavity of the hoof.

CAMOUFLAGING OF BLEACHING POWDER: Reports from France indicated that it was desirable to camouflage bleaching, which was being used to destroy mustard gas in shell holes, since otherwise the enemy would be able to easily get the range of his guns.

Extensive experiments with dyes and pigments were carried out under the direction of Lieut. E.P.Stevenson, with the purpose of securing a material which would deceive the camera and the eye, would blend with all backgrounds, would be fast to chlorine, and would not catalyze decomposition of bleaching powder.

It was finally determined that burnt umber alone (producing a brown tint) or mixed with small amounts of blue and yellow coloring matter (producing khaki tint), offered the most desirable coloring material. It was also demonstrated that these substances fulfilled most of the other requirements more satisfactorily than any other materials.

Airplane tests were conducted by Lieut. Abrams at elevations of 1500 and 6000 feet. The results showed that, whereas uncamouflaged bleaching powder was plainly

visible, both brownish and khaki colored powder were quite successfully concealed from the eye and the camera at these elevations.

PERMEABILITY OF SOUP POWDER BOXES TO MUSTARD GAS: In the early days of gas warfare as pursued by the Germans, it was customary to shell behind the lines with poisonous gases for the purpose of contaminating the food supply. With the development of gas shell and the use of mustard gas, the danger from this method of attack became very serious. The mustard gas vapors were extremely persistent, had a high degree of permeability, and were easily absorbed by many substances. The food supply of our army, therefore, had to be protected by special methods of wrapping.

In the field, one of the most easily prepared rations was made from "powdered soup", a powder which was wrapped in oiled paper, enclosed in a pasteboard box, which was again wrapped in paraffin paper. To test the permeability of this and similarly wrapped substances to mustard gas vapors, the material was removed from the box through two small holes. Glass tubes were inserted in these holes and sealed in place by paraffin.

The entire box was placed in an outer box through which air saturated with mustard gas vapors was passed. A slow circulation of air was maintained inside the soup box, and the effluent gas was tested according to the standard

procedure. It was found that in general mustard gas would not penetrate these boxes in less than $7\frac{1}{2}$ hours. The amount of mustard gas present would, therefore, not be at all harmful. In the case food was heated before use, heat would drive off or decompose any of the gas absorbed. Hence, while the use of gas with the intention of hampering the food supply might prove to be dangerous, proper preparation of the food containers would prevent any harmful effects upon the food.

<u>A FIELD DETECTOR FOR MUSTARD GAS</u>: All gases have characteristic odors, some more distinct than others. In low, although often in harmful, concentrations some gases give very little sign of their presence by their odor. With persistent gases, a harmful amount may be present for several days, and in dugouts and shell craters, lethal fumes may be present but unknown to the approaching soldiers. It is the duty of the gas officers and their men to explore and test the air and ground for the presence of toxic substances.

Mustard gas in particular, due to its persistance in trenches, shell holes, and dugouts, has caused many casualties. Ground that had been saturated with mustard retained the gas for several days. In the development work for field testing methods, the chemical addition products of any possible reaction and the reaction of reduction

products of dichloroethylsulphide were considered.

Color reactions gave promise of results and an electrical device for the decomposition and the subsequent reaction of these products gave very satisfactory indications. The air was drawn from over the surface of the contaminated earth, or from the air of a dugout, by an extension hose attached to the canister. This device, which was simple and compact, was placed between the hose and the canister. The canister protected the man from any gases not destroyed by the detector.

<u>THE OXOMETER FILTER</u>: The oxometer is a portable apparatus for producing oxygen gas from fused sodium peroxide. In producing oxygen, it was found that considerable quantities of caustic were carried over mechanically by the gas into the patients' lungs, and it was therefore necessary to introduce some type of filter to remove these particles.

Experimental runs were made in which five different types of fabrics were tested as filtering media. A fabric was finally selected which would completely stop the passage of caustic particles for a period of 40 minutes with an average pressure drop of 1½ inches.

The apparatus itself was so unsatisfactory in operation that the research finally concluded with an investigation of improvements to be made in generating the oxygen.

PRODUCTION OF LENSES FOR EYEPIECES: In producing the triplex lens for the eyepieces of the gas masks, numerous mechanical and chemical difficulties were encountered. This section was called in at various times to investigate and remedy these difficulties wherever possible. A large amount of this investigation was carried out by Lieut. Weber and Mr. Boynton.

For a long time the capacity of the Super-Glass Company had dropped to as low as 20,000 eyepieces per day, with 60% rejections. These rejections were largely due to "let-goes" (in which case the glass separates from the pyralin layer), cracks, "squeeze-outs", and dry spots. Most of these difficulties were caused by insufficient curing of the pyralin, and by improper methods of cutting and pressing the layers used in the eyepieces.

This section suggested a large number of improvements, increasing the production of the plant from as low an average as 20,000 lenses per day with 60% rejections, to as high as 50,000 lenses per day with 10% rejections.

ANTI-DIMMING MATERIALS: One of the chief drawbacks to the gas mask had been the dimming of the eyepieces. In both the old S.B.R. and the new Tissot types, the eyepieces fogged quickly in cold weather.

Many devices were suggested to remedy this defect, but most of them were not applicable to the masks already in production. The passage of the entering air over

the surface of the eyepiece, the use of transparent material other than glass, the separation of the upper section by a dam, and the use of double layer eyepieces were suggested and tried. The passage of the air over the eyepieces was perhaps the most satisfactory.

In the old type masks, having the mouthpiece, the simplest method was to treat the glass eyepieces with a chemical which would prevent the precipitation of moisture in small droplets, but would keep an even film of water over the entire surface.

Such material was developed by Dr. Spear and Mr. Stevenson of the Chemical Development Section, in conjunction with Capt. Carlton, and the Colgate Company. The material could be produced as a thick paste in stick form, as a thin paste in tubes, or as a liquid. The stick or tube form was the most desirable.

Special soaps with an excess of glycerine (to be rubbed over the surface and then wiped with a dry cloth) formed a film that tended to prevent the coagulation of droplet.

The trouble was not entirely corrected, but the mixture employed gave clear vision for several hours, depending upon conditions of use. The method of application to secure the best results was established and recommended, and all the masks were furnished with anti-dim.

HORSE MASK: A horse mask was developed, particularly with the idea of improving the old type mask so that mustard gas would be absorbed satisfactorily. The secondary consideration was that of lowering the resistance to breathing which in the old mask was sufficient to cause horses to collapse when laboring hard.

Two bags were made up of cheesecloth in the general shape of the old mask, one bag fitted within the other. The inner bag consisted of 4 plies of fabric, impregnated with the regular komplexene solution. The outer bag was made of 8 plies of cheesecloth and was impregnated with simplexene, which is a mixture of rosin, rosin oil, and paraffin oil. The proper composition of this mixture was determined in more than 200 experimental tests.

As to chemical protection, the new mask has held up satisfactorily against saturated mustard gas vapor for 90 minutes or more at a rate of 50 liters per minute over the entire surface. This rate is comparable with a horse's breathing rate while at rest. The resistence of the mask at this rate is not measurable. Protection against chlorine, hydrocyanic acid, and phosgene, is superior to that of the old mask.

The mechanical features of the mask were also improved, and actual field tests showed that this form of protection was worn by horses without any difficulty.

HORSE MASK

TESTS ON GALVANIZED IRON CLIPS FOR USE ON THE HORSE MASK: A series of tests have been made at intervals to determine the effect of ageing on the galvanized clips used in the horse mask. Tests of pin holes and thickness of the coating were not desired, but rather an idea of the results of prolonged contact with the hexamethylene tetramine used as a dope on the mask fabric.

Samples of the clips were weighed and immersed in the hexamine solution, and oxidation was determined by difference in weight after long exposure to the solution. Accelerated ageing tests were also made where the clips were exposed to steam and air over a considerable period of time, and the difference in weight, caused by oxidation, was determined. These tests gave a fair idea of the purity of the zinc, - an important factor in its protective properties.

RUBBER INVESTIGATIONS: Rubber in some form entered into most of the protective appliances used in gas warfare. The rubber investigations fell into two distinct classes : (1) chemical, and (2) mechanical. A unit with men from both the Chemical and Mechanical Development Sections of the Research Division was organized to work in conjunction with the Goodyear Company in developing the forms and modifications of rubber or rubber impregnated material that would be required in the defense program.

The chemical work was connected with different mixes, cements, fillers, and cures. The mechanical section considered the design and the physical properties of the product.

The early work was devoted to gas mask fabric, the earlier types using an impregnated cloth, and the more recent types a gum with stockinette backing.

The development of a horse mask resulted in two problems. The first was the stiffening of cloth strips by an inexpensive impregnation which would hold the bag of the mask open when in use. The second was a rubber or rubberized mouthpad for the masks. The mask is placed over the horse's nose, and the bottom of the bag is carried in the mouth. The pad is used to prevent the horse biting through the fabric, and to help keep the mask in position. The pad must be strong, flexible, and smooth, and due to the large number manufactured, the cost must be reasonable. Both solid cheap stock pads and impregnated fiber pads were tested. A heavy jute webbing with a skin coating of rubber proved to give a very satisfactory pad.

The flutter valve as first produced, while satisfactory, was open to improvement since the leakage was considerable and the valve was objectionably large. With the intention of improving the flutter valve, development resulted in the production of an arch type flutter valve

which was entirely enclosed in a brass casing with only the necessary air ports. The valve consisted of two arched circular discs. It was compact and mechanically strong. A great many trials were necessary to secure the best mix for these discs. They must hold their shape perfectly, and yet be elastic and of easy action to avoid high resistance.

The development of the felt filter brought up the problem of securing a gas tight joint between the edges of the felt. Sewing, rubber tapes, and various kinds of dope were tried. The most satisfactory solution was the vulcanization of the edges, using cement between the edges with a gum strip binding. Specially cured gaskets or washers were studied to aid in making the nozzle flange gas tight. As a protection against water, a waterproof cover was developed which was vulcanized to the edges of felt layers, at the same time the layers were cured. Needless to say, many cements and trials were necessary before a satisfactory joint was obtained. The signing of the armistice stopped further development on all these problems.

<u>COMPARATIVE FIELD TESTS ON THE EFFECT OF RESISTANCE AND DEAD AIR SPACE</u>: This series of tests was designed to give a qualitative idea of the effect of resistance and dead air space. The same test was run with (1) the complete mask, (2) the mask without the facepiece (canister, mouthpiece,

and noseclip only) and (3) the same as (2) except that an extra volume about equal to the dead air space in a Tissot mask was inserted between the flutter valve and the mouthpiece.

As a result of these tests and some other tests previously made, it was concluded:

(1) That resistance, up to at least the amount of exertion involved in a 4 mi. per hour walk, was not a significant factor compared with other faults of the present mask.

(2) It was inferred that resistance became of prime importance when a sudden burst of energy was made, and the body demanded the maximum possible supply of air (running until exhausted).

(3) There was apparently a noticeable but slight effect due to dead-air space under the rate of breathing while at rest.

(4) Under the rate of breathing involved in a 4 mi. per hour walk, there was no noticeable effect ascribable to dead-air space.

(5) The chief defect of the mask at that time was pressure on the head by the head-harness, resulting in a serious loss in morale and in physical disability.

(6) Less important causes of discomfort of like nature were fatigue from wearing the noseclip and in retaining the mouthpiece in position. Vision was not as good as

could be desired, and in close fighting or certain kinds of work, might have become a serious disadvantage.

PHYSIOLOGICAL STUDY OF THE GAS MASK: The demand for gas protection during the early stages of the war was so urgent that very little time could be given to the consideration of the best design with respect to the effect upon the wearer. The one idea was to secure protection and an immediate supply of masks.

It was soon found, however, that an excessive resistance to the flow of air so exhausted the soldier that he would become valueless in fighting. Experiments were then started to determine the relation between resistance and protection. The studies of the resistance in the various mask parts led to changes in design which gave much greater comfort to the wearer. Research on the resistance of the inlet and outlet valves and its effect on the mask leakage and comfort brought many weaknesses of the earlier types of mask that could readily be remedied.

This work was done under the supervision of Dr. W.K. Lewis, while leading physiologists were called into consultation. The greater part of the theoretical work was conducted by Dr. Pearce, assisted by Capt. Reiman of this section, at the Lakeside Hospital, Cleveland, Ohio.

With the adoption of the Tissot type facepiece, work was started on "dead air" space, and its effect upon

the wearer. The investigation covered the resistance of all parts, the amount of "dead air" space, the leakage. the inhalation and exhalation pressures, and volumes for different men under various conditions of activity, the fit of the mask, and the adjustment and types of head harness. Every point of the outfit was given careful consideration with the idea of perfecting the new mask so that it would cause minimum discomfort to the wearer, and yet afford adequate protection.

<u>THE INDUSTRIAL GAS MASK</u>: The use of a mask for protection against war gases led to numerous inquiries for similar protection against gases encountered in industrial practice. Requests had been received for masks to combat hydrogen sulphide, chlorine, carbon monoxide, sulphuric acid fumes, sulphur chloride, nitric oxide, ammonia, benzol, titanium tetrachloride and others.

A policy was outlined whereby suitable rejects from the American gas mask would be used in conjunction with standard canisters filled as follows:

Type A	All charcoal
Type B	All soda lime
Type C	60% charcoal - 40% soda lime
Type D	Pumice impregnated with copper salts (ammonia canister)
Type E	HC (carbon monoxide canister)

The absorbents were to be made up according to the specifications furnished by the Research Division and

canister packing was also to be done on specifications. The finished canisters were to be tested against gases encountered in industrial practice, and the Research Division was then to specify the proper type of can to be used in any factory.

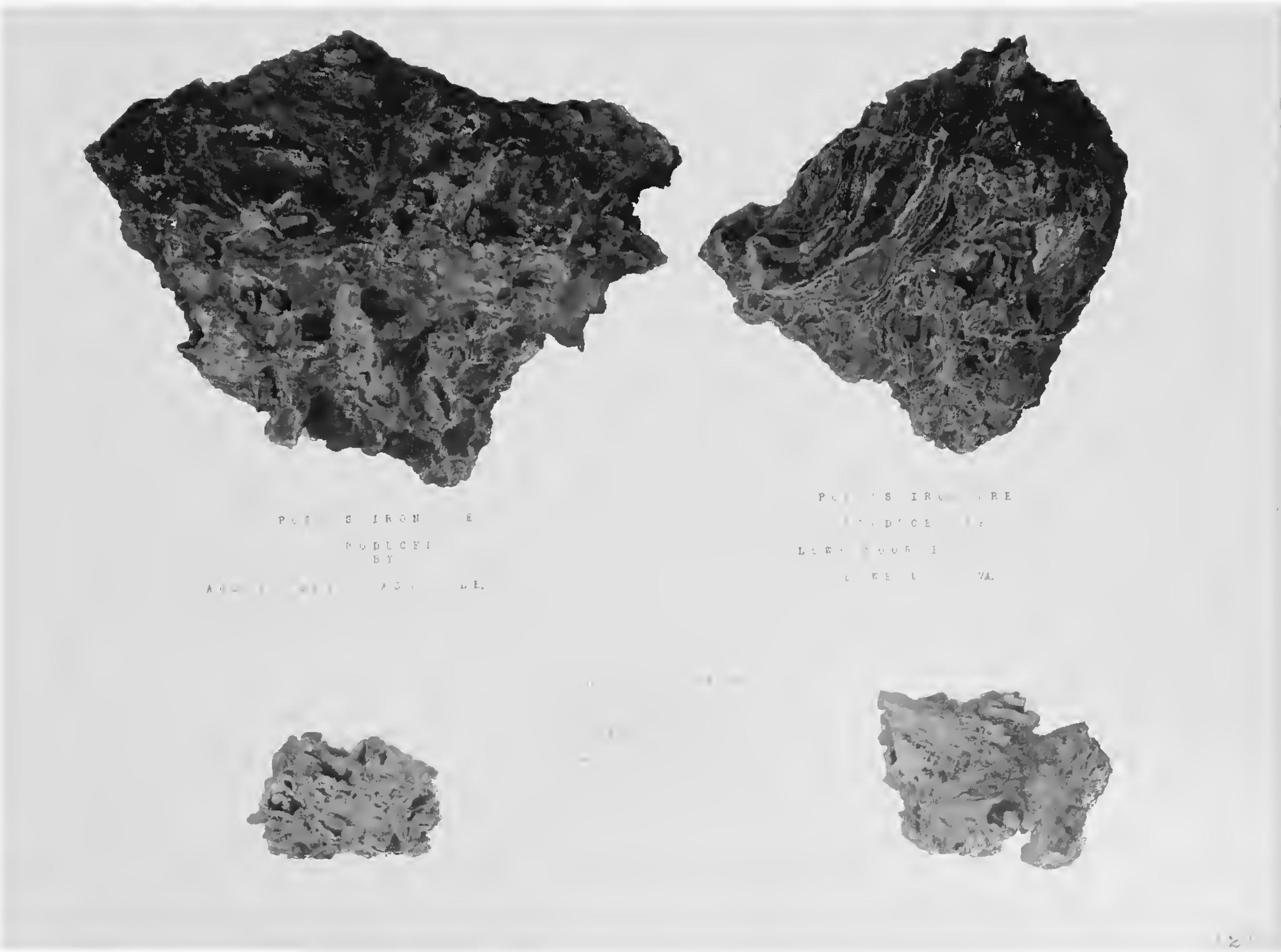
Protection against most industrial smokes was to be given by cotton pads in the canister. Wherever necessary, flat plate felt filters were to be specified.

These tentative arrangements were being put into execution when information was received that the Research Division would not be permitted to approve of industrial masks; that all information pertaining to these masks should be gathered together and published in technical journals; and that, thereafter, any concern could make and issue such masks.

HYDROGEN

PRODUCTION OF HYDROGEN: In June, 1917, it was learned that the government planned to build and operate hydrogen gas plants, employing the iron contact process. As this process was new and had been little used, Dr. W.K. Lewis decided to train men to serve with the Navy and Signal Corps in superintending the construction and operation of these plants. Consequently, J. H. Holton was sent to the Goodyear Tire and Rubber Company to study the process at their plant near Akron, Ohio, where Goodyear also maintained a large balloon testing station and flying field. Holton remained at the plant for about five months, and became thoroughly familiar with all the details, then went to Pensacola, Fla., and Atlanta, Ga., to study plants of the same type as it was planned to build at Langley Field, Hampton, Va.

In January, 1918, Holton visited Langley Field, and found that plant in the process of construction, but far from completion. A report on this trip was made to Lieut.Col. Geiger of the Balloon Training Section, Signal Corps. It was later decided to permanently detail another man, Corp. W. F. Tilton of this section, to the Hampton plant, so that he could be on the ground to supervise and inspect the technical construction. Once a month Holton visited the plant and went over the progress of the work.

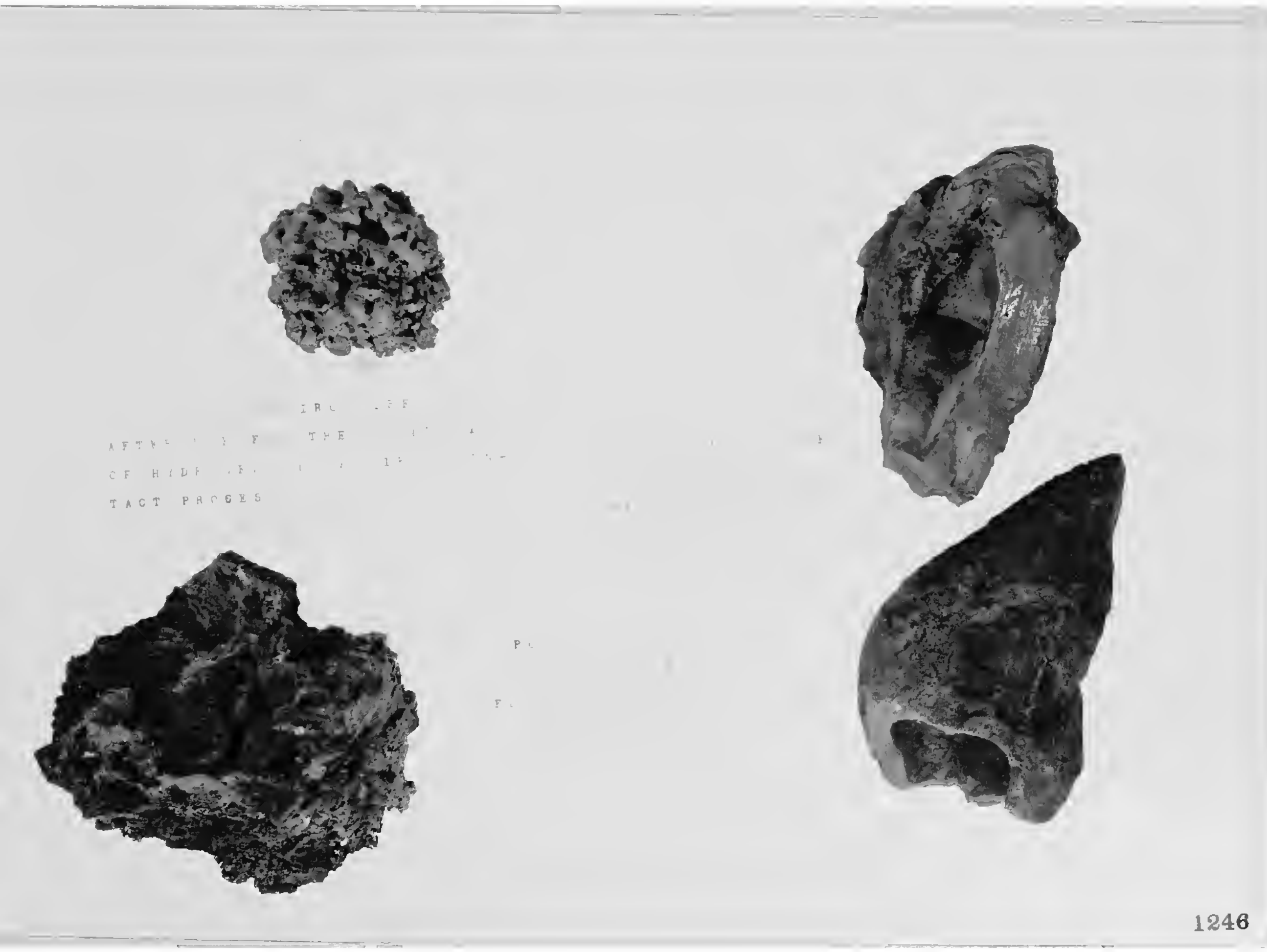


PRODUCTION OF HYDROGEN

PRODUCTION OF HYDROGEN

It was the duty of these men to furnish the plant with necessary office equipment and supplies of coke, coal, and wood. Many questions came up during the construction, such as the use of waterproofing cement, irregularities in high pressure piping, and other specifications upon which recommendations were to be made. Both representatives discouraged the idea of using the hydrogen plant as a gas plant to furnish heat and light for the field.

When finally the plant reached the stage where gas could be made, a sufficient number of men was detailed to learn the operation of this plant. Just before their training was completed, an explosion occurred which wrecked the blue water gas meter, and caused another delay of about six weeks. The contractor again announced that the plant was ready for operation, and this time a permanent detail of men was sent from Fort Omaha to carry on the work. As before, these men were trained by the contractor until they were ready to run the official acceptance test under the direction of the contractor. The Constructing Quartermaster directed the test to be run under the supervision of the representatives from the Chemical Warfare Service. This test proved to be unsatisfactory, and was later considered void. A second test was run in the presence of a number of officers of the Signal Corps of the Army as well as the Chemical Warfare Service representatives. This time the plant passed satisfactorily all requirements as to



1246

PRODUCTION OF HYDROGEN

capacity and purity.

Holton was then asked to serve on the Official Acceptance Board, which was to receive the plant from the contractor and turn it over to the Balloon Section of the Department of Military Aeronautics. This Board met in the latter part of August, and took the plant over for the government, presenting the contractor with a list of exceptions and unfinished work, and giving him until September 16th to reply. At that time the plant was formally turned over to the Balloon Section.

The plant was left in the hands of the officer-in-charge, with a trained staff of operators, and later a complete report was presented. A report was also presented on treatment and sources of porous iron ore for use in the plant.

HOPCALITE

PRODUCTION OF HOPCALITE: This section was designated to work with the Defense Chemical Research Section, to learn the method of making hopcalite (the new carbon monoxide absorbent), and finally to be responsible for manufacturing hopcalite on a large scale.

Small scale production was first carried out in Washington, with the assistance of Corp. B.T. Rauber. A thorough study of the important factors furnished the necessary data on methods of precipitating the oxides of cobalt, manganese, copper and silver. Information on filtration, pressing, drying, and grinding the oxides involved extensive work, but the necessary equipment was secured and the essential research was furnished in a short time.

The Navy had requested sufficient hopcalite to fill 50,000 canisters at the earliest possible moment. A contract was drawn up with the Rare Metal Products Company, Belleville, N.J., whereby they were to furnish all equipment and materials for large scale production, while the Defense Chemical Research Section would outline the experimental procedure, and our own section would then control the large scale production of hopcalite.

The plant was constructed in record time. Chemicals were procured, equipment was installed, and the first batches were laid down according to specifications. The inevitable difficulties, in passing from small scale to large scale production, were encountered and were solved by the men in charge. Filtering, pressing, drying, and grinding equipment was designed and installed.

The production of hopcalite was then carried on by this section to completion of the contract. This section also assisted in securing a satisfactory supply of calcium chloride to be used in driers for the hopcalite canisters.

<u>BENZOL, TOLUOL, AND XYLOL IN GAS TAR INTERMEDIATES:</u> Because the presence of cyclic saturated hydrocarbons influences the boiling point of the benzol series far out of proportion to the quantity of substance present, an investigation was instituted to determine a method of purification so that the boiling point might be used as an index of the aromatic constituents.

The literature on this subject was studied, and the most promising suggestion was the sulfonation of the aromatic hydrocarbons and their subsequent hydrolysis. The method, with its variations and limitations, was studied, and a schedule was determined which gave the most satisfactory separation.

The recovery did not prove to be quantitative, due to the loss of vapor and the formation of sulfones and carbonaceous residues. However, the losses appeared to be proportional to the amount of aromatic hydrocarbons present, and the purified liquids showed normal boiling points.

This method, while being far from perfect from an analytical point of view, offered one of the most rapid and accurate schemes for the analysis of the important aromatic hydrocarbons, benzol, toluol, and xylol in the presence of saturated aliphatic compounds.

TESTING METHODS

STANDARDIZATION OF TESTING METHODS: The first work done by Capt. Dickson was the standardization of testing methods, and this work was prosecuted continuously on testing machines in many of the laboratories. After visiting these laboratories, a report was submitted which included a ballot covering the chief points requiring standardization. A conference was held in Washington at which decisions were reached on these points and which, in a general way, guided subsequent standardizations. At this conference a coordinating committee was appointed to pass upon methods for official adoption.

The tests which were of the most importance or which have most required standardization, have been written up and approved by the committee, and issued as standard methods. Some methods have been written up in collaboration with the laboratory originating the test with a view to later standardization. In connection with this coordinating work, the laboratories were visited frequently in order to ascertain whether the standard methods were being followed, and to suggest improvements, to keep in touch with new methods, to select the best modifications for standardization, etc.

In conjunction with the committee on Field Tests at the University, active work was done in planning standard tests on gas masks to bring out the relative values of different factors.

Work was carried out in developing a smoke test (sulfuric acid), adapted to control testing in felt mills, in supplying standard apparatus, and in organizing control tests on the different machines.

The nature of the chief work was such that opportunity was presented for a large amount of miscellaneous liaison and consultation work, which, although rather intangible as to results, proved to be of value and importance.

The following standard methods were issued:

General Analytical Methods.
Standard Tube Test with Chlorine.
Standard Long Chloropicrin Method.
Accelerated Chloropicrin Method.
Standard Phosgene
Standard Superpalite Tube Test.
Standard Hydrocyanic Acid Method.
Standard Tube Tests with Arsine.
Standard Cyanogen chloride Tube Test.
Standard SO_2 Tube Test.
Standard Method for Screen Analysis.
Standard Pressure Drop.
Standard Detonation for Man-House Tests with Diphenylchloroarsine.
Standard Flange Tests for Smoke Filter with Sulfuric Acid.
Standard Flange and Canister Tests of Smoke Filters against Tobacco Smoke.

Discussion of Harness Testing.

NEW GASES.

PROTECTION AGAINST NEW GASES: During the early stages of poisonous gas development, many emergency problems were suggested regarding the protection offered against new gases. At the time the information was required, no standard methods of testing had been prepared, and the investigator had to devise a scheme for testing and interpreting the results. In some cases, the value of charcoal and soda lime for absorbing or destroying a gas had to be determined; in other the protection afforded by different fabrics had to be established.

In the early part of 1918, the value of charcoal and soda lime as a protection against mustard gas, xylyl bromide, and cacodyl chloride was studied. Analytical methods for quantitative determinations of the concentrations, and a method of determining the break points were developed and used. Special absorption apparatus had to be constructed for each case due to the different physical properties of the different gases. A large amount of this work was done in Philadelphia at the plant of the United Gas Improvement Company by Mr. E. R. Bridgewater.

With the development of vesicant gases, protective devices had to be designed that would keep the defense program apace with the offense work. The effect of new gases, chiefly forms of mustard and Lewisite, on both the

existing devices and on all new material, was studied and recommendations on the necessary changes or new developments were made. As in the earlier tests, both the form of apparatus and testing procedure were developed for the work Some of the important developments dependent upon this work, were the dugout blanket, horse mask, and protective clothing.

SOLUTION OF GASES IN SULPHURIC ACID SMOKE: The use of sulfuric acid smoke in felt testing demonstrated that it was very penetrating but had little irritating power. It seemed, however, that some toxic gases might dissolve in this smoke. Preliminary work was carried out at the Massachusetts Institute of Technology by Lieuts. Spofford and Abrams, but the resultant qualitative tests indicated that chloropicrin, phosgene, and chlorine were but little dissolved.

Further experimentation and a study of the factors involved in such solution, were carried out under the direction of Mr. Stevenson. His results also demonstrated the fact it would be impossible to dissolve sufficient quantities of toxic gases in the sulfuric acid smoke to be of any considerable value in offense operations.

DISTRIBUTION OF CHLORINE IN GASSED CANISTERS: Canisters were gassed with phosgene as on a usual test, and then samples of the absorbent filling were carefully removed

from known locations in the canister where it was suspected that the insertion of special baffles might increase the utilization of the absorbent. These samples were then quantitatively analyzed for chlorine. The percentages of chlorine were indicated on a drawing of the special canister so as to give a graphical idea of the distribution of the gas in relation to the structure of the canister. It was found that (1) ring baffles were of some value in breaking up channeling near the sides, (2) that center baffles were of doubtful utility, and if used at all, should be perforated; otherwise the absorbent immediately over the center of a solid baffle was relatively useless, and (3) that wave-front method could not replace the present method in deciding upon the merits of special designs, since the former was qualitative while a quantitative study had to be used to determine the relative utility of different portions of the absorbent.

INTERMITTENT FLOWMETERS: In canister testing, it was desirable to reproduce as closely as possible the human breathing rates. Special mechanisms were developed which gave intermittent flow that very closely corresponded to the actual breathing rates. To secure these conditions, complicated mechanical valves and pumps were used. In an endeavor to simplify the apparatus and to provide an easily portable set for intermittent canister testing, an auto-

matic water flowmeter was developed. It consisted of a U tube with a by-pass connecting the lower arm of one side with the upper arm of the other side. As air pressure was applied to the side with low by-pass connection, the water column was forced down and below the by-pass opening until sufficient pressure was built up to force water out of the by-pass. Air flowed through the by-pass until cut off by the returning water. A very careful study of sizes of pipes, valves, and air chambers was necessary to secure a form that would function properly. A further study would, however, be required before specifications could be drawn up for the construction of a machine which would give <u>any</u> rate cycles per minute, and percentage time of inhalation and exhalation.

This work was undertaken at the suggestion of John B. Dickson, and the work already done was carried out under his direction.

MISCELLANEOUS INVESTIGATIONS: In the work of the Chemical Development Section, many problems were started and turned over to other organizations when the fundamental principles had been determined. In other cases, work was started in conjunc tion with other departments. After a short preliminary study of the chemical nature of the problem, the balance of the work and mechanical design would be worked out by a division dealing with that type of problem. A large amount of work was done in control testing and in technical advising of other departments.

A few of the minor problems handled in this way are listed here for reference:

1. The testing of adhesive tapes used in mending gas masks fabrics.
2. Testing double loop noseclips.
3. The path of diphenylchloroarsine through the felt filter.
4. Special research on diphenylchloroarsine testing methods.
5. Corrosion tests on metal hooks and buckles.
6. The ageing of elastic webbing.
7. The effect of simplexene and komplexene on elastic webbing.
8. The strength and physical properties of pyralin for gas mask eyepieces.
9. The design of experimental rotary steam activating furnaces for charcoal.

In all development work, this section allowed its men to remain with the work until new men were well trained. Often this section transferred some of its best men to take charge of the actual operations, thus insuring the success of the undertaking after it had been taken over by the Manufacturing Division.

WAR DEPARTMENT

CHEMICAL WARFARE SERVICE

RESEARCH DIVISION

AMERICAN UNIVERSITY EXPERIMENT STATION

WASHINGTON, D. C.

MAJOR GENERAL W. L. SIBERT, DIRECTOR

COLONEL G. A. BURRELL, CHIEF OF RESEARCH DIVISION

MECHANICAL RESEARCH AND DEVELOPMENT SECTION

B. B. FOGLER, IN CHARGE

SUMMARY OF ACHIEVEMENTS

1917 - 1918.

MECHANICAL RESEARCH AND DEVELOPMENT SECTION

HISTORICAL

This group was organized as a unit on September 4, 1917, under the direction of Mr. H.H. Clark, who was transferred from the Pittsburgh Station of the Bureau of Mines to take charge of the work. The demand for this unit arose from the fact that while the primary research on the majority of problems connected with gas warfare is chemical, the most of the devices developed for this purpose require a properly designed physical housing before they can be successfully put into field service. This group was created to meet this need by working in cooperation with the various chemical research groups which then existed or were later created in connection with this general research work.

As originally organized, the unit consisted of two main sub-divisions, - first, a group of research mechanical engineers and their assistants who were provided with office and laboratory space for properly carrying out their work; second, an instrument shop equipped to fabricate the various designs developed by the engineers in the first group. The problems coming to this group might be placed under five main headings:

(1) The development of devices used for the army as defensive equipment in gas warfare.

(2) The development of devices used by the army as offensive equipment in gas warfare.

(3) Gas defense equipment required by the navy.

(4) Equipment required by the navy in connection with the various pyrotechnic signal devices upon which this Station did a large amount of research work.

(5) Miscellaneous problems connected with the design of special mechanical apparatus for use in the various laboratories throughout the Station.

The organization continued along these lines until May 4, 1918, when the volume of work necessitated a subdivision of the work under which the group of men working on army defense problems was separated from the rest of the section and put under the charge of Mr. B.B. Fogler, the balance of the section remaining under the direction of Mr. H.H. Clark.

On June 25th, the entire personnel of the group known as the War Gas Investigations of the Bureau of Mines was transferred to the War Department, and became the Research Division of the Chemical Warfare Service. This transfer was made in connection with a complete reorganization of the various groups working on different problems of gas warfare, but had little effect on the internal work of the various

sub-divisions at the American University, except that it was the beginning of the more complete militarization of the personnel engaged in this work.

On August 3, 1918, the mechanical work at the Station was again reorganized. In this change all the work of a research nature both for the army and navy was placed in charge of Mr. B.B. Fogler, while the instrument shop and a part of the draftsmen engaged in miscellaneous service work were transferred to the service unit of the Administrative Section under Mr. Richmond Levering.

In view of the fact that the mechanical research work for the entire Station began and ended in a single group, this final progress report will cover the various research activities along this line carried on since the beginning of the work on September 4, 1917. No attempt will be made to correlate, except in a general way, the problems and the personnel engaged upon them, as these will be found in detail in the individual reports on the various problems to be found in the files of this section.

ARMY DEFENSE PROBLEMS

ARMY MASK. Very naturally, one of the chief problems undertaken by this group was the development and refinement of the army gas mask. In considering the large amount of work done on this problem, a logical sub-division may be made between the facepiece and the canister, for the reason that

with the possible exception of the type in which the absorbent is an actual unit with the facepiece, as is the case with the French "M2" mask, or practically a unit, as exemplified in the German mask, neither of which played any great part in the defense research of this country, the various types of facepiece and canister are interchangeable with one another.

Army Facepieces

Box Respirator. The standard box respirator mask produced by the Gas Defense Division was modeled very closely after the English mask. For this reason, the work of this Station on the development of the facepiece consisted principally in improvements in the details of construction and the development of a suitable mask fabric.

The problem of the noseclip, spring and pad, and their location in the mask was carefully worked out. A rubber pad shaped like an inverted cone was designed which is a marked improvement over the British type. The spring itself was studied and an instrument developed for measuring the pressure exerted by the spring against the nose.

An improved design for the die casting, which gives a lower resistance, was submitted to the Gas Defense, but was not adopted. Considerable work was also done to improve the vision of the eyepieces, resulting in the adoption of triplex glass and an efficient non-dimming mixture.

BRITISH BOX RESPIRATOR SHOWING
COTTON WRAPPED NOSE CLIPS

AMERICAN BOX RESPIRATOR SHOWING
IMPROVED RUBBER NOSE CLIPS

NOSE STOPPER FOR NEGRO SOLDIERS

Interior view of the mask with nose
stopper in place.

NOSE STOPPER FOR NEGRO SOLDIERS

Pad and harness removed from the mask and fastened in place on negro to show the position assumed by the stopper when in service.

Side View

NOSE STOPPER FOR NEGRO SOLDIERS

Pad and harness removed from the mask and fastened in place on negro to show the position assumed by the stopper when in service.

Front View

The question of a suitable fabric for the facepiece was taken up by the Gas Mask Research Section. Suitable methods for testing the resistance of various fabrics to penetration by gases were developed and standardized. A great variety of fabrics were tested and a high grade rubber coated fabric found to be most suitable.

American Mask of "M2" Type. During the latter part of 1917, designs were drawn up and several hundred experimental masks manufactured along the same lines as the French "M2" mask, in which the lower part of the facepiece consists of a pad of several layers of cheesecloth containing an absorbent impregnation. The adoption by the army, however, of the box respirator type, together with the promising features of the development work then being carried on in the direction of the Tissot type, led to the abandonment of any further work along these lines.

Tissot Type. In October 1917, the first American Tissot type mask was made by the Mechanical Section of this Station, assisted by Dr. Geer of the Goodrich Rubber Company. It is designed on the principle of the French Artillery mask. The facepiece is made by cementing two pieces of red rubber together. The seam extends directly down the front of the mask and under the chin. A narrow reinforcing strap of the same material is put around the edge of the mask to form the eyepiece frames.

AMERICAN MASK "M2" TYPE

Copied from French Mask.

The protection afforded by this type of mask depends on a tight seal between the rubber and the face, the wearer breathing in the natural manner through the nose and mouth. The incoming air is led through Y-shaped rubber clarifying tubes inside the mask, so that it strikes the lenses, clearing them of condensed moisture. The exhaled air passes out through a flutter valve of English design protected by a guard of sheet aluminum.

The eyepiece frames are similar to those used in the French Fabric mask, being held in place by lugs which are bent under the glass. The chin rest is made of aluminum and covered with a section of rubber tubing. The angle tube is designed as a casting, but is hand-made, embodying all the principles of the present Tissot type die casting. The head harness is made of strips of soft rubber so arranged that two straps pass around the back of the head while a third connects these two with the top of the mask in front.

<u>B.M. Tissot</u>. The Bureau of Mines Tissot, as it is commonly known, is a further development of the original mask described above, and represents the development between October 1917, and April 1918, when the mask was turned over to the Gas Defense Division to be put into production. The facepiece is made of two layers of calendered stock, an inner layer of soft, elastic rubber, and an outer protective layer of tough black stock. It is cured on an aluminum form, which gives a

AMERICAN TISSOT TYPE MASK

Side View.

AMERICAN TISSOT TYPE MASK

Interior View

AMERICAN TISSOT TYPE MASK

Die casting with chin rest, inhalation (clarifying) tubes, exhalation flutter valve and guard, and breathing tube which connects with canister, assembled in position.

smooth-finished interior, and causes the mask to fit the face tightly around the borders, and yet clear the nose in front.

The eyepiece frame is molded separately, and cemented to the facepiece in a semi-cured condition. The facepiece is then put on the former, the head-harness of rubber straps attached, and the whole cured in one operation in dry steam.

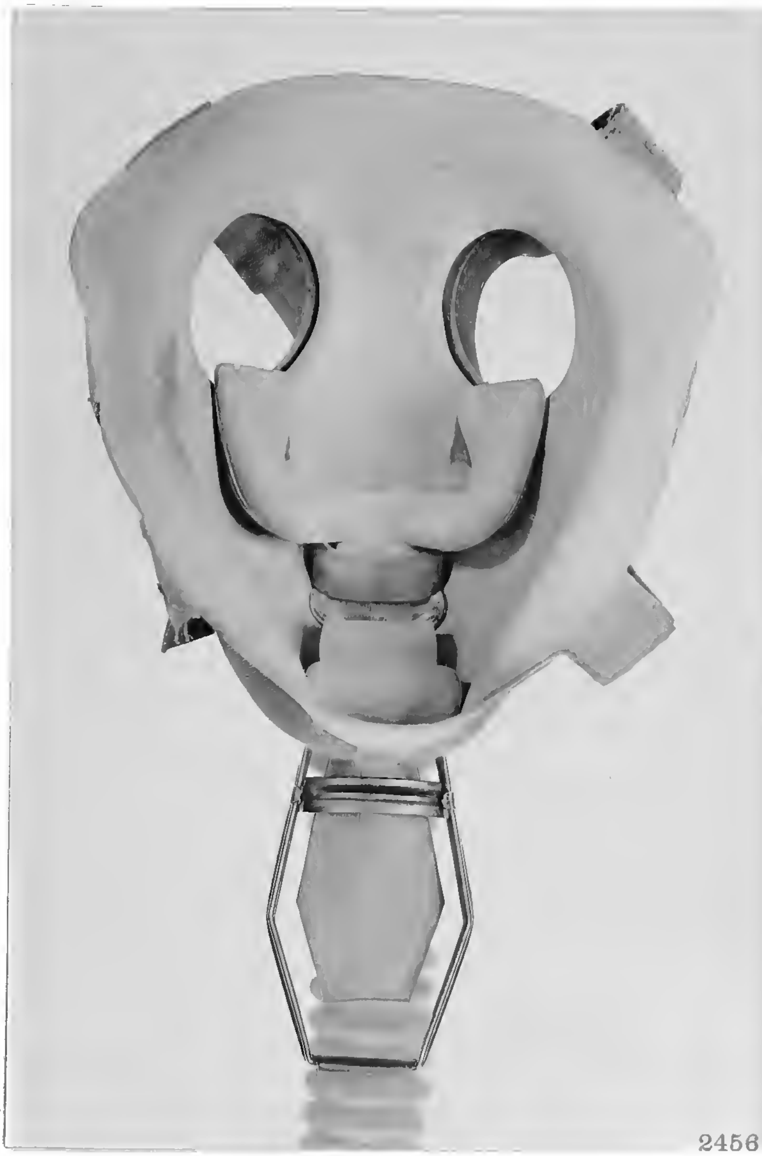
The clarifying tubes and chin rest are of molded rubber and assembled at the same time as the die casting and eyepiece frames. The clarifying tubes are the same design used at present, and deliver the incoming air directly against the eyepiece lenses. The chin rest is made with rather long horns so as to hold the mask firmly in place.

The present Akron Tissot is a further development of the B.M. mask. The principal alterations are the stockinette covering for the facepiece which replaces the black protective rubber, alterations in the aluminum form to give greater space between the mask and face, stiffening of the facepiece, and a head-harness of elastic webbing.

Whittlesey Mask. In April, 1918, Dr. Whittlesey of the U.S. Rubber Company developed the idea of applying a rubber coating to stockinette on a calender, cutting out the facepiece, cementing the seam under the chin, and curing the mask on a flat form of wood or metal. A number of these masks were made for

WHITTLESEY MASK

One piece mask, seam under chin.



DIPPED MASK

One piece seamless mask, stockinette covered.

this section and thoroughly tested. It was found that while extremely light and comfortable, they developed a tendency to collapse around the nose, thus interfering with respiration. This difficulty was remedied to some extent by insertion of stiff reinforcing stripsat the cheeks, but the mask was never put into production.

The Dipped Mask. A method for manufacturing the Tissot type mask by dipping the forms into a solution of rubber, was developed by the Ravenna Rubber Co. in conjunction with the Mechanical Section.

The facepiece of this mask was formed by dipping an aluminum form into a solution of a suitable rubber compound in naphtha. When a sufficiently thick layer of rubber had been formed by successive dips, the rubber was covered with stockinette, a reinforcing strip placed around the edge, and the mask cured in dry steam. This process gave a well-finished process without seams. The method was turned over to the Gas Defense Division to be put into production.

Howe Type Mask. A number of experimental masks were made by this Section at the Howe Rubber Company to determine the advisability of placing the stockinette inside of the masks. The masks were made of the Tissot type with the stockinette on both the inside and outside of the facepiece, and as an intermediate layer. An olive green, non-blooming rubber compound was used for the facepiece, eliminating the necessity

of dyeing the stockinette. The mask with stockinette inside was reported very favorably on field test, the fabric being more comfortable than rubber against the face.

Miller Type Mask. In April 1918, a special Tissot type mask was produced by this Section which embodied several novel features. The inside clarifying tubes are eliminated. The inhaled air passes from the die casting, through an intake tube up the front of the mask and is introduced through the facepiece between the eyes. It is directed against the lenses by a baffle of rubber. The inlet tube of the die casting is at right angles with the flutter valve and allows the flexible tube to be carried over the shoulder. This permits tipping the flutter valve and guard forward so that it will not strike the chest when the head is lowered. Masks of this type were made up with both black rubber and stockinette reinforcement.

The mask was criticized because the attachment of the inhalation nozzle to the die casting on the outside of the facepiece necessitates two openings into the mask and therefore doubles the possibility of leakage.

In order to meet this objection, two other types were made involving the same principle. The first made use of the regular Tissot type die casting which requires but one opening through the facepiece. The inhaled air enters through the casting, and is led into the external chamber through an

LATEST TYPE MILLER TISSOT MASK
WITH GEER CARRIER.

INTERIOR VIEW OF MILLER TYPE
TISSOT MASK SHOWING SPONGE
RUBBER DAM AND VENTILATING
TUBES.

opening in the inner wall, and is distributed between the eye-pieces in the same manner as the mask described above. The general comfort and efficiency of this mask was improved by altering the size and shape of the curing form to eliminat all unnecessary dead air space.

A second mask of the same general type was designed in which the inhalation tube, clarifying tube and eye frames are molded in one piece. The inlet tube comes in from the left side under the eyepiece and curves up between the eyes. The air passes out through a simple brass stamping which permits the flutter valve and guard to be inclined at a very large angle from the chest. The lower portion of the mask is designed so as to fit the contour of the chin eliminating the necessity of a chin rest.

The mask is fitted with a non-dimming arrangement consisting of a soft sponge rubber dam which fits over the nose and cheeks, separating the eye chamber from the lower or respiratory portion of the mask. The dam is pierced by two curved rubber tubes which deliver the air directly under the nostrils. The inhaled air then enters the mask between the eyepieces and is distributed against the lenses by a baffle. It is then passed down through the "ventilating" tubes to the nose. On exhalation the check valve in the canister closes preventing the moist air from returning through the "ventilating" tubes and thereby dimming the eyepieces. The

ventilating tubes contain enough dry air from the inhalation to take care of the difference of pressure between the two chambers at the beginning of exhalation. Sample masks of this type have been given complete tests with excellent results in regard to comfort, resistance and dimming.

Kraus Type. A mask of special design has been made by Dr. Kraus of Clark University at the Hood Rubber Co. It embodies the non-dimming principle of ventilating tubes and is equipped with a by-pass so that only a portion of the inhaled air is drawn over the eye-pieces. The oval eyepiece frames are molded as a unit and fit tightly to the eyes like goggles. A flap fits around the nose preventing exhaled air from returning to the eyechambers.

The angle tube is molded rubber and contains three brass tubes for inhalation and one larger one for exhalation. The facepiece is built and cured on an aluminum form. Tests show that this type of mask gives an excellent range of vision, is comfortable, and does not dim at zero Fahrenheit.

Development of Snout Type Canister. Late in the summer of 1918 development work was undertaken to produce a mask of the general type of the German and French ARS masks, with the idea that a mask of this type might be more effective as a piece of equipment for offense operations than one in which the canister was carried in a separate haversack and attached to the facepiece by a connecting hose. It was found, however,

DR. KRAUS' "UNIVERSITY MASK"

UNIVERSITY MASK

Side View

UNIVERSITY MASK

Interior view showing one-piece molded clarifying tubes and rubber flap over nose.

that in order to provide an adequate filter to remove the various toxic smokes which were being used in increasing amounts, would entail the addition of so much weight and breathing resistance in the canister that this work was given up after a few experimental models had been made.

Canisters for Army Masks.

Standard Box Respirator Canister. When this experiment was started, about the first of August, 1917, the army canister was in production as a 2-3/8" x 4-5/8" oval, corrugated can, 7" high, with valve seat in the canister bottom and nozzle soldered to the top. Inside a fine wire dome screen about 1-1/2" high covered the full are of the bottom, and above this were packed three layers of charcoal - soda lime mixture, the layers being separated by cotton wadding pads. Above the mixture was a layer of turkish toweling upon which was a stiff, flat screen, and the whole held down by two rectangular springs each having two prongs which were forced under inwardly projecting ears at the top of the canister.

This canister was, in practically all details, a copy of the British canister, and was giving general satisfaction for war gas protection.

Study of Standard Canister. For months, the canister work of the Mechanical Research Section, under the Bureau of Mines,

consisted of a detailed study of the existing canister and its component parts in relation to air flow resistance, chemical life, moisture effects, mechanical durability, etc. From these studies we have reports as follows:

RESISTANCE OF CANISTER MIXTURES:
- Factors affecting resistance of mixtures.
- Variations due consolidation.
- Effect of size of granules.
- Effect of depth of mixture.
- Effect of pressure.

RESISTANCE OF CANISTER FILTER PADS:
- Factors affecting resistance.
- Effect of pressure.
- Effect of thickness of pad. (No. of layers)
- Variation in area.
- Effect of previous history.
- Effect of weight of pad.
- Effect of humidity.
- Resistance of pads between layers of mixture.

RESISTANCE OF MISCELLANEOUS PARTS OF CANISTER:
- Resistance of base plug.
- Types of rubber check valves.
- Resistance of base plug and old type valve.
- Resistance of base plug and new type valve.
- Notes and conclusions on base plugs and valves.
- Resistance of packing screens.
- Resistance of top outlet orifice.
- Resistance of toweling.
- Resistance of convex screen and spider.

CANISTER PACKING SPRING.

LIFE TESTS ON CANISTER CHEMICALS.

TESTS ON CHANNELING.

EFFECT OF JOLTING.

Study of Modifications. In addition to the study of the existing canister, some work was done on suggested modifications, such as check valve guards to prevent the valves from being

blown off by explosions, special hemispherical dome screens to improve chemical life, moisture detectors to be inserted inside canister to show if a canister had been damaged by dampness, effect of various arrangements of baffles and cotton pads on the resistance and life.

Type Changes of Standard Canister. About January 1, 1918, the standard canister was changed to Type G, which differs from the older Type C principally in that it is only 5-1/2" high. Type H succeeded Type G about April 1, and differs from it only in the interior packing. About July 1, Type J became standard, this still retaining the 5-1/2" height, but decreasing the amount of packing mixture so as to leave about 1-1/2" at the top empty. This unused space required a change of spring to the Z type. The above changes in the standard canister were not made by this Station, but are here referred to as each change called for corresponding tests and investigation work.

Dudley Canister and Mask. Some effort was spent in developing the so-called Dudley canister and mask. This canister was a small metal can with a central breathing tube extending to the bottom, air passage being in through a perforated top, through the mixture, through a perforated diaphragm to the end of the breathing tube. A mouthpiece was attached to the outer end of the breathing tube.

The Dudley outfit differs from the navy snout type canister mask, which it somewhat resembles, in that the mask was designed to fit the face between the nose and mouth and enclosing the eyes and nose only. This apparatus seemed to give little promise and was abandoned.

Smoke. About the first of the year 1918, reports from abroad made it apparent that protection was needed against toxic smokes, as well as against gases. It appears that some of the solid or liquid substances fired in shells to vaporize into poison gases were shattered by the explosion of the shell in such a way as to form minute particles of solid or liquid, so fine as to remain suspended in the air.

Such particles are not chemically removed by the war gas material but pass mechanically between the granules and find a free passage to the man's lungs. While it is quite possible that these "smokes" were produced accidentally at first, it is probable that their continued use was intentional and was studied so that the fineness and penetrating qualities were improved.

Smoke Protection by Cotton Pads. The cotton pads which had used in the canisters were good enough filters to stop some of the first smokes, and the early work on smoke protection was directed to improving the filter qualities of the pads. It was soon found, however, that to make better filter pads, the resistance must be greatly increased, but the canister

resistance was already so high as to be very uncomfortable, if not sometimes actually unbearable. To overcome this objection, some of the early designs of filter canisters were provided with a mechanical valve which could be manually operated to by-pass the air around the filter when the canister was used against gas alone, or so set as to make the air pass through the filter. This gave fairly low resistance when the valve was set for gas protection only, through the canister with no pads, but resistance even higher than with the standard canister when valve was set for gas and smoke protection through filter and canister. One real objection to this arrangement lies in the uneasiness caused by introducing a factor of uncertainty among the men during a gas attack, since each man must decide for himself when he is getting a smoke. The filters designed for use with this arrangement were also entirely inadequate to protect against the finer smokes.

<u>Fine Smoke Filters.</u> It was apparent from a study of possible filter materials that a filter for the fine smokes must have a high resistance per unit area. In order to get the large area necessary to bring the total resistance within reason, experiments were made along three general lines; one the formation of a filter into a bag, cup, or jacket to surround the outside of the canister; the second to use an arrangement compact enough to go inside of the canister; and the third

to make the filter as a separate unit to be attached to the canister by an air connection. We had reports that the British were successfully using thin, creped, sulphite cellulose wood pulp paper for filters, and our early efforts were made using such a material.

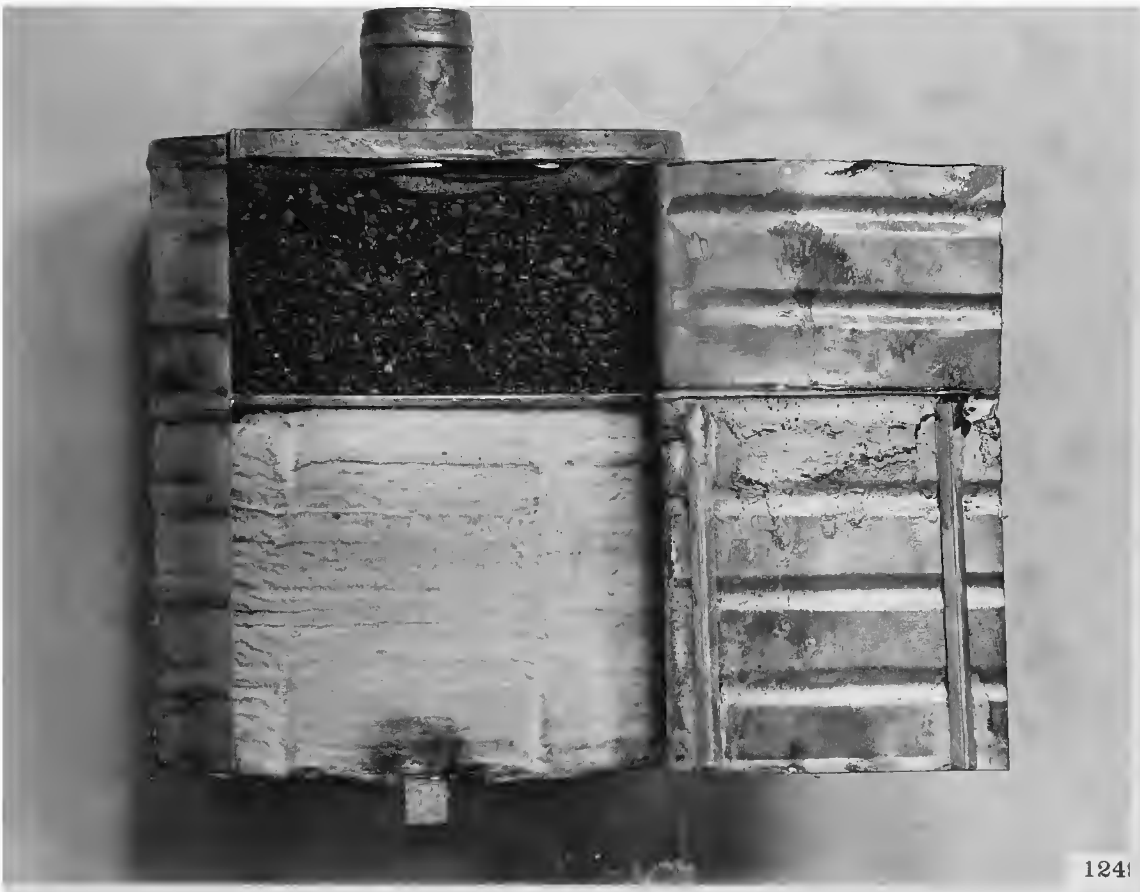
Cover Cartridges. Sample of the so-called "Cover Cartridge" developed by the G.D.S. were sent here and we did some work winding sheet papers in multiple layers on similar jackets, and sealing the ends with various cements. The care necessary in such winding and in the sealing of the ends, as well as the irregularities of the tests on such filters due to variations in the material and in its application, even in skilled hands, show that a simple filter and one which can be produced with a greater degree of precision is necessary.

Early Filters. The reports of work during the first four months of 1918 show wrapped paper filters, attempts to use bags of felts and similar materials, internal filters of "doughnut" form made of crepe paper discs piled up, and internal filters of felt in both folded and accordion forms. As we have since found out, these early filters contain the ideas necessary for success, but, due to lack of proper material, or to not going far enough in getting large area, they had, in general, higher resistance and lower protection than desirable.

Doughnut Filters. The so-called "doughnut" type of filter consists of a ring, or wall of filter material about an inner

EARLY DOUGHNUT FORM OF CREPE PAPER FILTER

EARLY DOUGHNUT FORM OF CREPE PAPER FILTER



CREPE PAPER DOUGHNUT FILTER CANISTER

hole, so that a horizontal section resembles a doughnut. The first filters of this type were made of doughnut-shaped layers piled up and the pile sealed at top and bottom to the canister so that the air had to pass through the walls parallel to the layers of paper. Experiments with doughnut filters of sulphite-cellulose crepe paper were continued for several months, study being made of various papers, direction of crepe in layers, methods of making discs, methods of building filters, etc. This line of investigation was finally dropped, as there seemed small hope of getting reliable and reproducible results.

Molded Pulp Filter. A direct successor of the crepe paper doughnut filter was the molded pulp filter which started about April 1st with a doughnut-shaped filter, cut from a block of pulp molded by draining the water from a thin solution of Scott tissue paper, then drying in an oven. This gave such promise of filter qualities, together with ease of production, that a great deal of effort was spent to develop filters of this general nature. The Albemarle Paper Mfg. Company gave great assistance in this research. Pulp blocks were made of various substances such as cotton fiber, poplar soda pulp, and spruce sulphite pulp. Several methods of molding were tried, such as forming by compression, by bottom gravity drainage, and by side gravity drainage. Attempts were also made to mold one or more of the faces into the finished state. With these various pulps and methods of molding, other things were tried such as vibrating the mold, heating the pulp,

cooking the pulp, soap powder, different lengths of fiber, stirring mechanically or by steam jet to remove air bubbles, molding into blocks of various sizes, different rates and methods of drying, etc. Much of this work was done to eliminate cracks and fissures which formed in the blocks during the drying.

Result of Molded Pulp Filter Development. By December of 1918, this process had been so far perfected that many doughnut filters had been made which showed entire protection for sixty minutes on man tests against detonated diphenylchlorarsine with resistance of about 30 mm. of water at the standard rate of 85 l/m. It is safe to say that little more experimental work would be necessary to make filters of this type reproducible and capable of being manufactured in large quantities.

Molded Pulp Flat Plate Filters. Parallel to the development of the doughnut filters from these molded pulps, another form of filter using the same material was studied. This consisted of a flat plate of the filter material of suitable thickness (1/2" to 3/4"), and of length and width corresponding to height and width of the canister. It was proposed to seal the edges of this plate to the edges of the side-flow canister. This general development, though incomplete, gives indications of a possible form for a good filter canister.

Head Canister. Going back now to the period of January to April 1918, a minor investigation was made of the possibilities

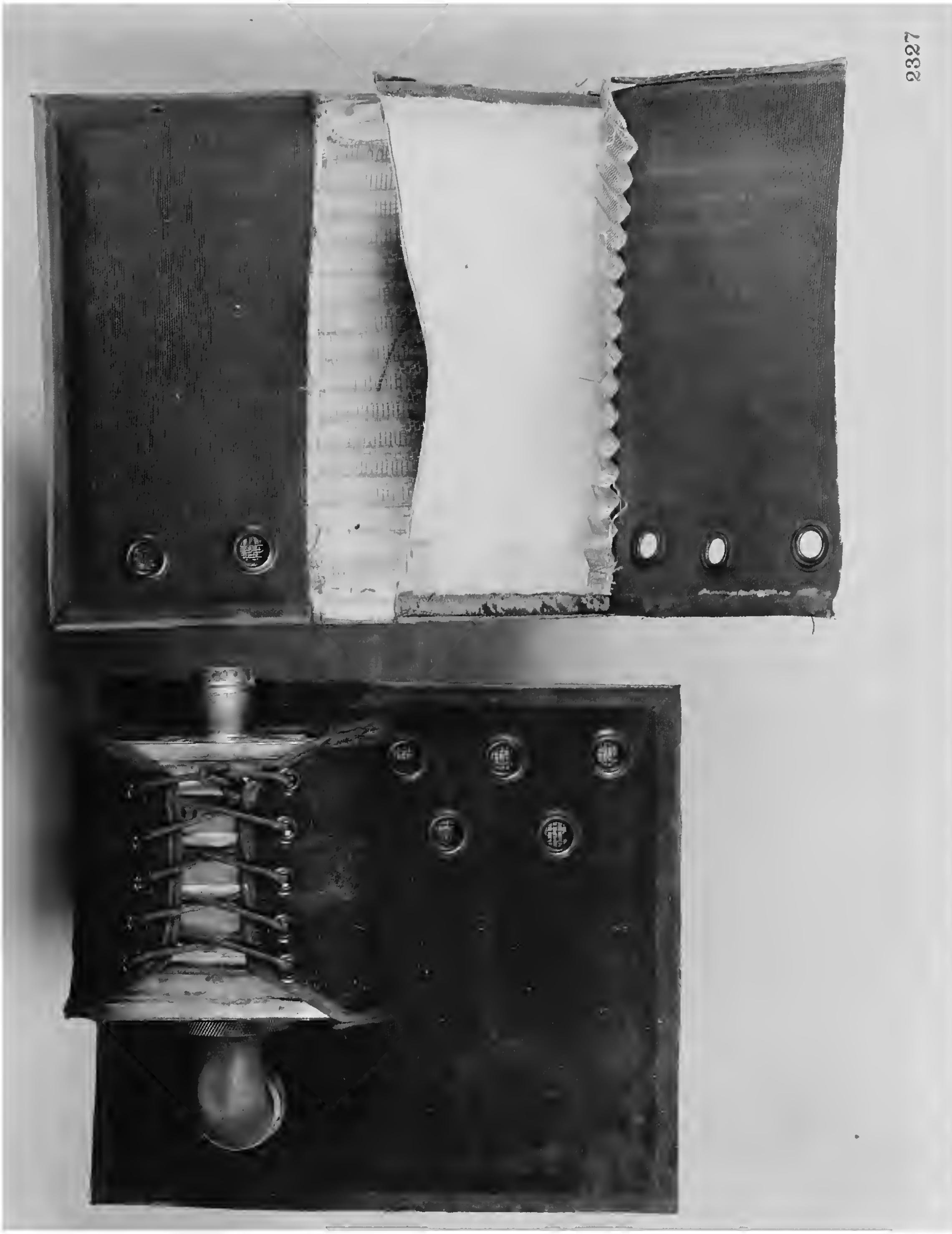
MOLDED PULP BLOCK AND DOUGHNUT FILTER

MOLDED PULP BLOCK AND DOUGHNUT FILTER

of developing a canister to be worn on the head. A number of shapes were made, including cylindrical cans, oval cans, and cans of curved section, all intended to be worn at the back of the head and supported by a hood attached to the mask. None of these contained any smoke protection. The possibilities of this head-carried type ofcanister did not appear to have much value from the army standpoint, and as an army investigation was dropped. The work was carried along as a naval problem and resulted in the navy head canister, as reported elsewhere.

Artillery Canister. Another investigation of this early period of 1918 was the attempt to develop a low resistance canister without smoke protection, but with a life against war gases approximately equal to that of the standard canister (Type G). It was thought that such a canister would be of value to artillerymen or others who were required to make violent exertions during periods when not encumbered by the equipment regularly carried on the back. A canister of 2-5/8" x 6-7/8", oval section, 5" high and packed with 8-10 mesh charcoal and soda lime, gave the desired protection with a resistance of about 25 mm. of water at the standard rate of 85 l/m. This canister was never put into service, owing to its considerable weight and also because of the increasing need of smoke protection.

Flat Plate Felt Filter. Starting in June 1918, investigation work was done to make filters from sheet felts by fastening



FLAT PLATE FELT FILTER

Cut to show construction

the edges of two rectangles of the material together, and breathing through a nozzle from the space inside. The rectangles were proportioned to give total filter areas of from 100 to 150 sq. in. Various methods of fastening the edges were tried, such as gluing with felt glue, marine glue, or rubber cement, sewing, vulcanizing or a combination of these. To keep the inner surfaces apart for air passage, spacers were tried of corrugated wire screen, corrugated sheet fiber, corrugated and perforated sheet fiber, woven wire (bed spring style), woven wire (door mat style), expanded metal, expanded fiber, etc. Several methods were used for attaching nozzles, using screw clamping parts, or parts to be secured by flanging or crimping. To make the outfit practical, a rain shield is necessary, so various types of waterproof fabric cases were devised. These again required separators to space the fabric from the filter surface. Small canisters were developed with a special nozzle at the air inlet and with means of securing this nozzle to that of the filter. It was intended to carry the outfit in the regular knapsack by removing the central partition.

The laboratory tests results on these filter outfits were highly satisfactory. Nearly all the methods of fastening the felt layers together gave good filters, but the vulcanizing process was selected as being a practical method and giving best mechanical strength. An objection to this filter

is the difficulty of securing the large quantities of felt and its high price, about one dollar per filter. It was also thought very desirable to make the filter element to be contained in the canister, because of the military difficulty of training the men to use and care for a new and different piece of apparatus. For these reasons and because a number of these outfits gave rather poor results in a very severe field test, work was dropped on this type of outfit.

Flat Type Paper Filter. A minor development of the flat plate investigation was the design of an outfit to use plates of thick paper somewhat like blotting paper, which has been found to possess good filter qualities. This outfit consists of two tin plate shallow-dished covers, the surfaces of the covers having half-round bosses formed inward. One of the layers of paper is fastened to one cover by a nozzle which makes a tight joint between nozzle, cover, and paper. An embossed tin air spacer is placed between this first paper and a second paper layer, then the second cover applied and the edge folded over the edge of the other cover, the fold clamping the papers tightly and making a filter-type tight joint. While this construction showed possibilities in laboratory test of making good filters, the outfit seemed liable to mechanical injury by bangs on the sides or edges, so that the work was dropped.

Accordion Filter. Another line of attack on the smoke filter problem was the development of large surface, internal filters,

ACCORDION FILTER CANISTER

Views showing construction.

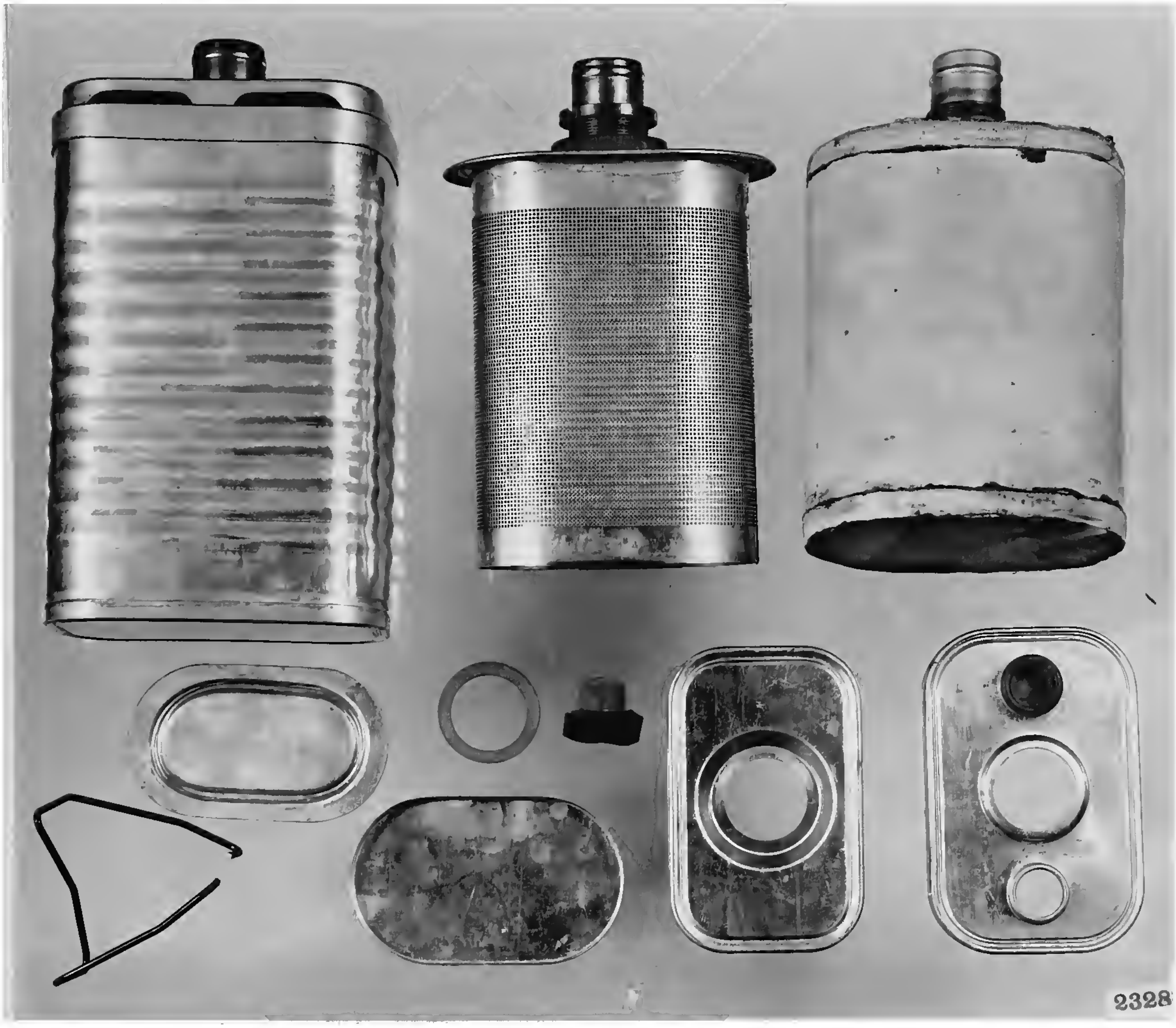
of accordion-like form. This form was first suggested in January or February of 1918, and studied until late October. The early efforts were to assemble comparatively small discs of felt, each having a hole in the center, by fastening together alternately the outside edges and edges around the hole, of a pile of discs, making an accordion-like structure with large area and comparatively narrow, but numerous air passages. Among the methods tried for fastening the edges were felt glue, crimped metal rims, piling with rigid air passage rings and clamping the whole filter endwise. After a fairly satisfactory and compact filter had been developed, using the felt, it was suggested in June that paper be substituted to reduce the cost, Subsequent work was devoted to paper filter. After many papers and methods of construction had been experimented with and hundreds of man tests made to try them, a canister was developed with war gas material in the upper half and a special blotting paper filter in the lower half. The layers of this final filter were cut to the general form of the inside of the canister and just small enough to allow air passage. Each layer was embossed with a raised edge on one side and a raised rim about the hole on the opposite side, Pairs were built up by gluing the outer raised edges of two discs together, a metal air passage ring being incorpor ated between the two. The two pairs were built up on a spider fitting the central holes and clamped tightly

together and also to the war gas container by means of a screw in the spider.

<u>Accordion Filter Canister</u>. The canister designed for use with this filter is of the general shape and size of the new British canister, the L.I.L. canister and the 1919 canister, having a round-cornered rectangular section, 3" x 4-5/8", and a height of 6". The upper half above a central diaphragm is packed from the top with the war gas material. The nozzle at the top may be unscrewed, exposing a flat, inhalation valve. The filter is fastened to and suspended from the diaphragm at the bottom of the war gas material chamber. The lower half of the canister covering is fastened to the upper part of the canister at the corners only, leaving four slots half way up the canister for air entrance.

This filter canister showed satisfactory gas and smoke resisting qualities with a total resistance of about 50 mm. at the standard rate of air flow. It also presented little mechanical difficulty in construction and could be made by standard machinery. It is probable that this could have been put into production with satisfactory results had not development shown possibilities of even simpler filter construction.

<u>1919 Canister</u>. In October the Long Island Laboratory brought out their design of the so-called "1919 canister", which consists of an oval section, perforated metal, war gas material container with a central, flat, perforated breathing tube



1919 FELT FILTER CANISTER

connected to a nozzle at one end. After this inner container is packed with the war gas chemicals, a filter jacket of felt is slipped over it and the top edge sealed to the inner container. A rectangular, corrugated case forms the outside, and to this is soldered a top having a hole for the nozzles. This top also has two holes in which are placed rubber inhalation valves of a type developed by the British. A second cover above the first forms a rain shield, and this is secured by a nut on the threaded nozzle which clamps rain shield, outer can cover, and inner container together. This canister is the type accepted for production just before the time the armistice was signed, putting a stop to all development work. In accepting this type, a reservation was made that a cheaper and simpler filter should be substituted for the felt filter if one could be developed.

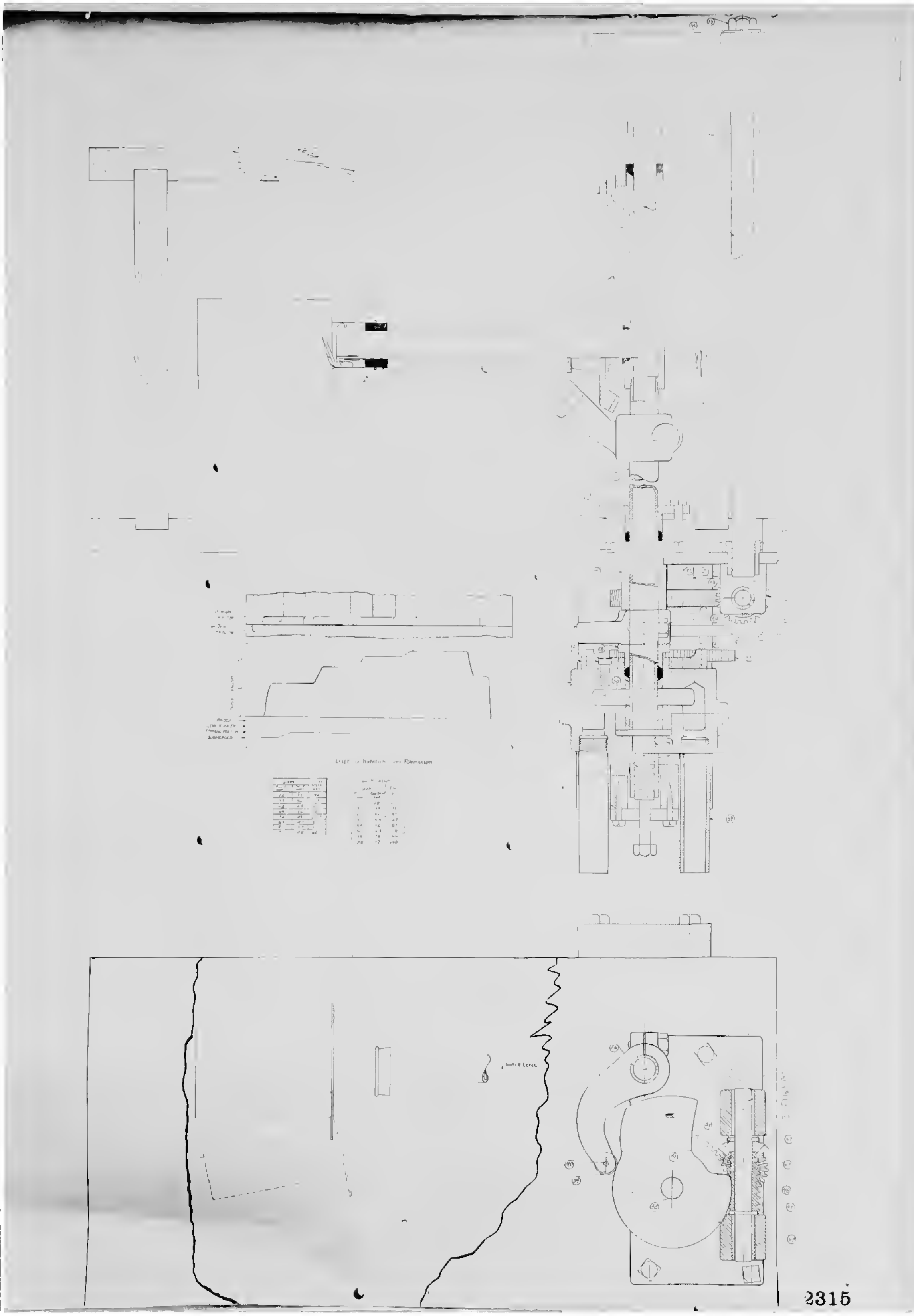
Wrapped 1919 Canister. Attempts were made to put paper filter on the 1919 canister by wrapping with layers of paper. Some of the papers developed for the accordion canister and some special papers developed for this purpose were applied to the war gas material container of the 1919 canister by wrapping and sealing the edges. In some cases, layers of course burlap or mosquito netting were applied between the layers of paper to give mechanical strength and air spaces. With the various papers, filters were tried having from 2 to 20 layers, and giving resistances between 20 and 60 mm.

WRAPPED PAPER FILTER FOR 1919 CANISTER

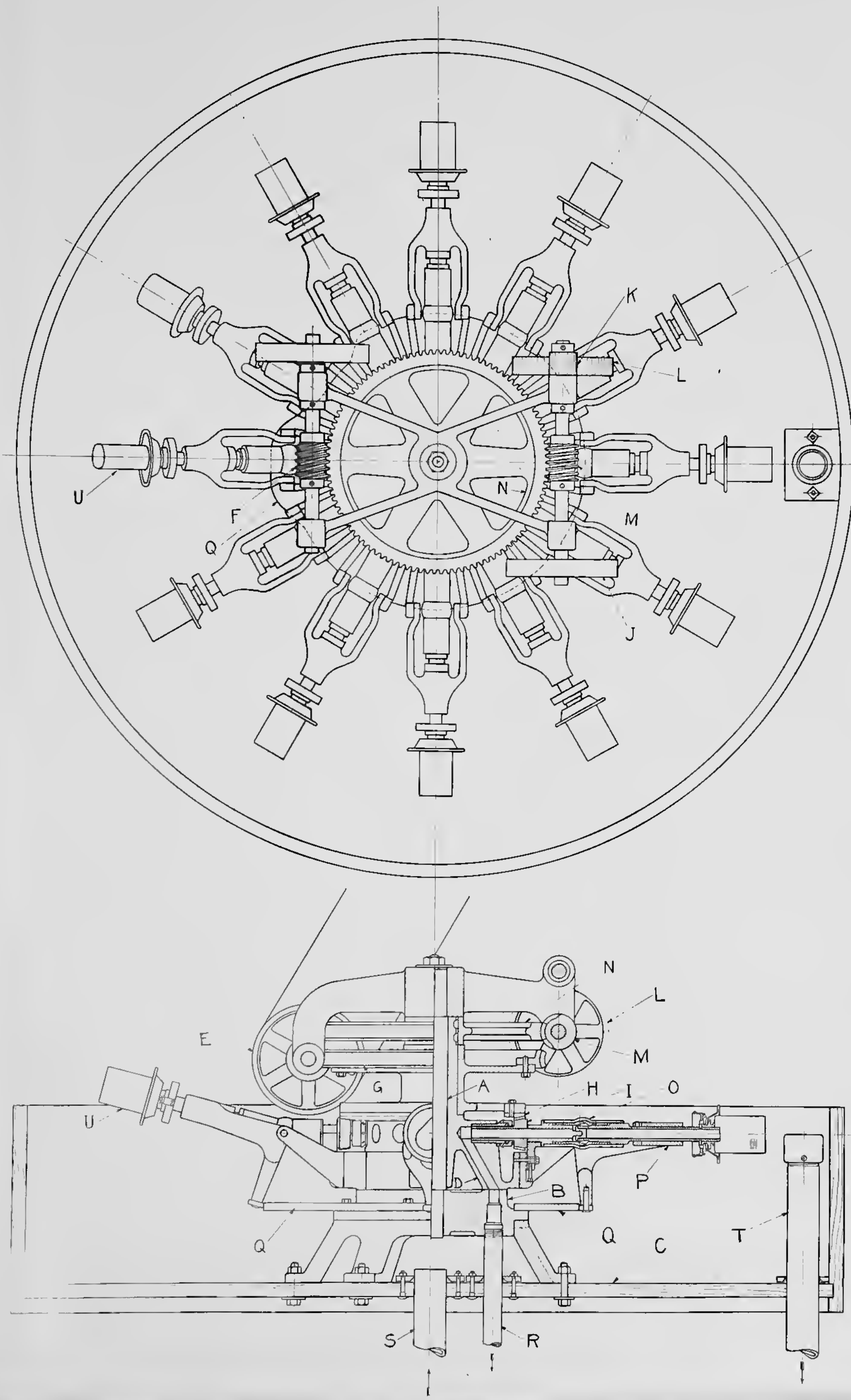
at the standard rate of air flow. Man tests showed protection against detonated diphenylchlorarsine for times varying from -0 to 60 minutes (the full time that tests were run). The fact that many filters gave good protection shows that a filter of this type and material is possible, but the operations of wrapping and sealing require careful work in production and inspection, and even with the greatest skill and care, imperfections are almost impossible to avoid. This chance of defects together with the labor involved makes the process undesirable.

Sucked-On Filter. In August a suggestion came from A.D. Little, Inc., to mold or form a fiber filter jacket on the outside of a fine screen frame by suction from a water pulp solution. They also suggested cotton-seed hull fiber as a very promising material for this form of filter. The first filters based on this idea were made by holding and rotating the screen frame by hand in a tub containing the solution, suction being applied by means of a hose leading from a pump. Early in October, a simple machine was installed by means of which better control could be secured of such functions as rotation speed, depth of immersion, concentration or solution, suction, pressure, etc. With this machine the problem was studied until the last of November, making filters in the form of a cup which could be slipped over the "1919" war gas container and sealed to it at the upper edge. Attention was

"SUCKED-ON" FILTER AND 1919 CANISTER



EXPERIMENTAL, AUTOMATIC MACHINE FOR "SUCKED-ON" FILTERS



WAR DEPARTMENT
CHEMICAL WARFARE SERVICE
RESEACH DIVISION

MACHINE FOR FORMING
SUCKED ON FILTERS
IN LARGE SCALE PRODUCTION

CAPT. E.D. LAMBERT
DEC. 26, 1918.

2323

given to such points as proper mesh of wire for the frame, possibility of removing the frame after forming, effect of various fibers and methods of treating them, concentration of solution, suction pressure, rotation speed and depth of immersion. In addition to this a method of compression of the material after function was devised to secure greater density and compactness. The method and rate of drying of the filters play an important part in the final state of the material and required considerable study.

<u>Sucked-On Filter Machines</u>. Early in November it was realized that we were making filters of uniform good quality and that the development could be hastened by constructing a machine with automatic features capable of producing filters on a large scale. The United Shoe Machinery Corporation understood the design and construction of a machine, but before much had been accomplished the signing of the armistice caused the order to be cancelled. At this time it still seemed desirable to construct an automatic machine, though of simpler and cheaper design and smaller capacity, to complete the development work on the filter, and this was designed and drawn before an order came to cease all experimental work by the end of the year.

<u>Future of Sucked-On Filter</u>. The work on this sucked-on filter and apparatus for making it was in a very satisfactory state of development when the end of hostilities removed the military necessity for smoke protection and made further work

useless. Had the war continued, there is little doubt but that this filter would have been used with the 1919 canister with satisfactory results from the standpoints of resistance, weight, mechanical strength, cheapness, rapidity of construction and protection.

Conclusion. The type of canister first used, which followed former British design, served throughout the war with only very minor changes in details of construction and packing, and it gave excellent protection. The efforts to modify and improve that canister gave no result that warranted any radical change, though those minor changes gave valuable improvement in the protection. The principal new work done was in developing smoke filters. After studying the many types suggested, a few, including the 1919 felt wrapped canister, the same canister with sucked-on filter, the accordion filter, and the molded pulp, doughnut filter canister, were developed far enough so that had the need continued, any one of them could have been produced in quantities to meet army requirements. The sucked-on filter canister seemed, by far, the simplest, cheapest, and most practical form.

The Carbon Monoxide Army Canister. Work was started on this problem at the request of Dr. W.K. Lewis, who had been advised of the need for army protection against carbon monoxide by members of the A.E.F. and of the British Liaison Service. The device was intended specifically to be used in pill boxes

from which machine guns were fired and in sapping and mining operations. A suitable canister filling material to absorb CO had already been developed in the form of Hopcalite, but it was practically impossible to get any details, or in fact any general information as to the probable requirements that a canister would have to fulfill. At first a concentration of one percent was assumed but later .1 percent was considered as the probable maximum. The length of time the canister would have to operate was also taken at a high figure and later reduced when it was found that the absorbent materials were more effective than had been anticipated. The whole problem should only be attacked by assuming certain hypothetical conditions and attempting to design an apparatus to meet them. A can of approximately the size of the regular army canister was finally developed that was thought would give sufficient protection for any ordinary needs. Several attempts were made to secure adequate information by sending cablegrams to the C.W.S. Director in France and also to members from the American University going overseas, but no information of any sort was ever received. It was assumed, therefore, that either the problem was not of the importance imagined or that changing conditions had rendered the use of a carbon monoxide canister unnecessary to the army. The work was carried on in cooperation with the Defense Chemical Research Section under Col. A.B. Lamb, and was completed with

the final report of Mr. M.H. Reymond.

<u>Quick Detachable Hose Connection</u>. During the work of this section on canisters, a number of instances developed where the need of a quick detachable hose connection appeared desirable. A great number of suggestions were considered to meet the conditions of absolute tightness, easy operation, and means of easily locking a connection in place, against accidental derangement. A careful study was also made of the patent literature. A form was finally developed utilizing a spring washer to clamp two flange faces together with a suitable gasket interposed between them. The flanges were attached either to pieces of the hose or to the canisters as was desired. Two overlapping cylinders or cylindrical cups containing slots through which extensions of the spring washer were extended were used for the clamping means. One of these cups was placed under one flange directly while the other had the spring washer interposed between it and the flange. After being locked in position, the gasket was therefore always under spring tension while a positive section of metal was utilized to prevent the flange parts from being pulled out of contact. The connection is fully described in the report by Mr. M.H. Reymond.

<u>Canister Dust Filter</u>. The work on this problem was started following receipt of a cablegram from abroad stating that danger existed in dust from canister materials being drawn

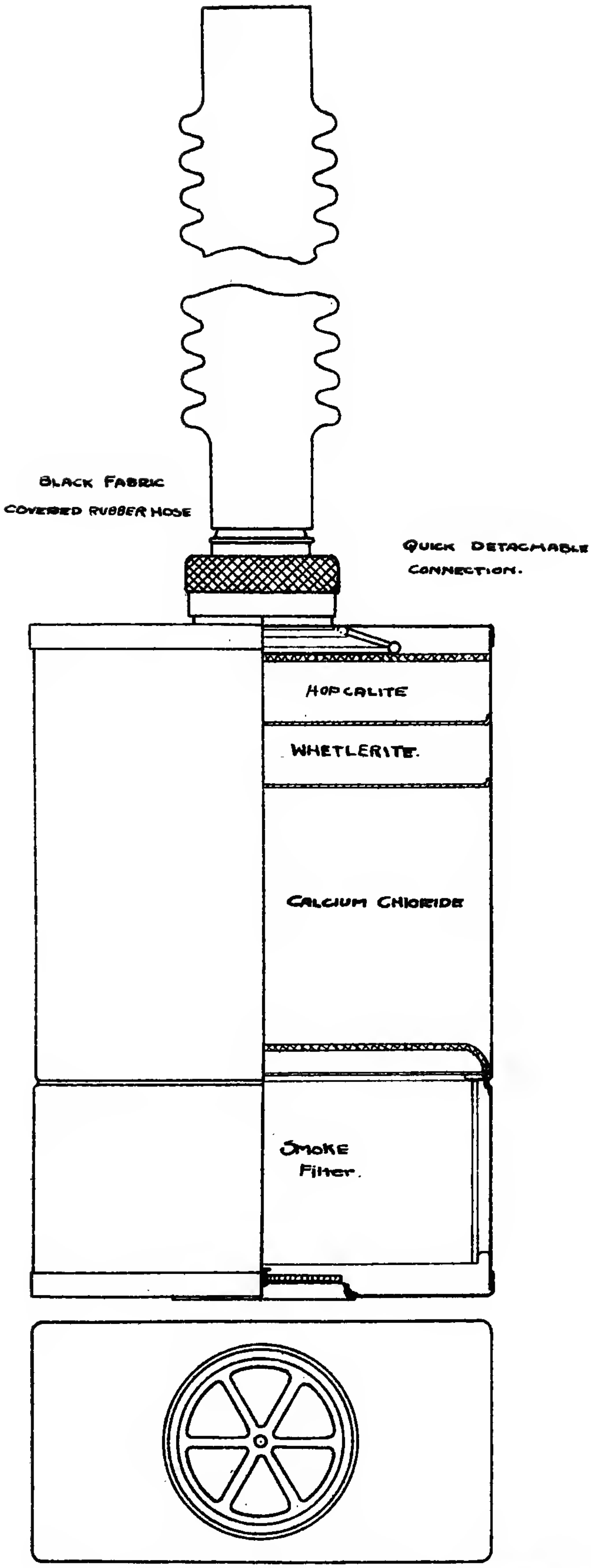


PLATE III - FINAL DESIGN OF SINGLE UNIT-ACMA-CANISTER.

into the new Tissot type masks. It was feared this would affect the eyesight of the user or dim the goggles. Careful experiments were begun to try out a large range of fabrics which would have the properties of low resistance and effectiveness in stopping canister dust. Dust was produced experimentally by grinding up charcoal and soda lime and weighed amounts were utilized in a special apparatus to obtain quantitative results. Several materials were found suitable, the best of these being cotton wadding compressed in layers of the proper thickness. The next best material was a form of true cotton felt and this was more practical for use for many purposes than the cotton wadding since it could be used in sheet form. A sample of cotton table felt also showed desirable properties. A number of wool felts gave excellent results, but were deemed too expensive to employ. Final tests were made on the materials properly placed in canisters by men with Tissot masks under heavy exertion on an ergometer. No dust sufficient to affect a man was drawn in, using the best samples. The work is completely covered by final report of Lieut. P.E. Sprague, Pvt. R.S. Mariot and Pvt. M. Prozan.

Summary of Work on Paper Development. Early in the year 1918, the use of toxic smokes in warfare necessitated the development of a filter which would successfully remove suspended particles without offering a high resistance to the passage of air. Paper offered one of the most promising materials

for this purpose, and several lines of investigation were independently started at government laboratories and private mills. In July 1918, this work was coordinated under the direction of Dr. Wm. Bovard. Work was first concentrated in developing a paper for use in the accordion filter simultaneously with the development of this filter mechanically, and the efforts of the laboratories were systematized so that work would not be duplicated, - work on paper using wood pulp was confined to the Forest Products Laboratories, investigation with rags and cotton linters was done at the Bureau of Standards, and puffed paper and sheets containing celite and diatomaceous fillers were developed at the Clapp Laboratory. The commercial field was canvassed for a suitable paper, but with the conclusion that the most promising industrial papers, namely, blotting, filter, and unsaturated felt papers, were all too hard and compact.

Considerable experimental work showed the superiority of a thick, single-ply paper. Mr. Ellerson of the Albemarle Paper Mfg. Company, offered the use of his mill for an experimental run, and a thick rag sheet was produced that was tested extensively in the accordion filter and gave very good protection against smoke. A portable pressure drop apparatus was developed to facilitate mill testing of the paper, and trials proved that this paper was reproducible and that the manufacture could be easily controlled. This paper was also

efficient when used in the flat plate filter.

In October 1918, the development of the Logan or 1919 canister entirely changed the paper situation. The most advantageous method of using paper with this canister consists of wrapping the material around the canister. The thick paper used in the accordion filter was not suitable for this form, and so new papers were developed for the purpose of wrapping the canister with from 4 to 20 plies of the paper.

Photomicrographs of many fibers were made at the Bureau of Chemistry, Department of Agriculture, and these, together with a study of the paper making qualities of fibers, indicated the superiority of raw cotton, cotton linters, wool fibers, and celite as raw materials. Raw rags and linters were developed at the Bureau of Standards; relations were obtained showing the variation of density, resistance, and other properties with composition and machine conditions; and a paper was developed that when wrapped ten times around the canister gave a fairly low resistance and good protection. Wool, by reason of the serrations and physical properties characteristic of animal fibers, seemed particularly suitable for use in smoke filter paper, and in work done at the Forest Products Laboratory, efforts were made to utilize the short wool fibers that are not used in making blankets, clothing, or other essential war materials. Mixtures of wool, rag, and specially treated wood pulps were used; variations of physical

properties with change of composition and conditions of manufacture were studied; and a paper was developed that when wrapped six times around the canister gave good protection with a low resistance to the passage of air. At the Clapp Laboratories, mixtures of wool, rag, patented puffed paper, and celite were developed, but this type of paper never reached the same degree of perfection.

The mechanical strength of the wool paper was improved by forming the sheet on netting, and as this did not impair the efficiency in any way, the resulting paper was very well adapted to wrapping the 1919 canister. This paper was developed at the termination of the work, and was not exhaustively tested, but showed great promise for use in wrapping the canister for protection against toxic smokes, and with an area of 75 sq. in. have good efficiency with very small resistance.

Protective Clothing. With the advent of mustard gas the need arose for clothing to protect the wearer against its action not only under field conditions, but in factories and shell loading plants where the gas was manufactured and loaded in the shell. Inasmuch as this gas not only attacks the exposed portion of the skin but very rapidly permeates ordinary clothing, it became necessary to provide a complete head to foot outfit which, in combination with the mask would entirely shut off any access to the skin of an atmosphere containing mustard

gas. The problem was still further complicated by the fact that the majority of materials which are impermeable to mustard gas also prevent the transpiration of air, thus holding in the heat and moisture given off by the body and almost completely stopping the necessary access of fresh air to the pores of the skin. The first material which was found available for this purpose was the linseed oil impregnated sheetings which were developed almost simultaneously by workers in this country, in France, and in England. Two suit designs were developed, one for field use, following the general lines of the union overall, but designed with a view to tighter closure at the wrist and ankles and opening in the front. A cowl was attached to this suit which overlapped the edge of the mask, thus clothing the entire body with the exception of the hands and feet. Samples of this suit were made up and submitted to the Gas Defense Division. A second type of suit was developed for factory use, made in the main of the same material, but differing from it principally in the provision of a special helmet in place of the mask and a means of ventilation by compressed air. So far as we know, this suit was never put into use, due in part to the restricted range of action of a man attached by a hose to an air line and, also on account of the difficulty of securing a supply of compressed air at a pressure which could safely be introduced within a suit of this nature.

AIR LINED HELMET AND SUIT

Front View

Showing suit inflated.

Owing to the unsatisfactory situation in the matter of suits for factory use, research work was conducted by a group of chemical engineers working under the direction of Lieut. Abraham to produce a material which would allow a reasonable skin ventilation and still protect the skin against the action of mustard gas. A fabric was finally produced consisting of a sheeting coated with a mixture of glue and gelatine which allowed the transpiration of moisture nearly as rapidly as the uncoated fabric and yet offered a high degree of protection against the passage of air containing mustard gas. It should be pointed out that while this fabric did not allow the transpiration of air, it was demonstrated that a large amount of the discomfort arising from wearing the linseed oil coated suit was due to the fact that it prevented the evaporation of moisture given off by the pores. This fabric was not suitable for field use, however, on account of the fact that under the action of water in liquid form, such as rain, the coating stiffened, and after prolonged service it cracked. This fabric was, however, finally recommended to the Protective Clothing Committee as the one best suited for factory use.

Late in the summer of 1918, a request was received from the A.E.F. to put into production at once suits and gloves for field use along the lines of samples of suits and gloves sent by a courier. This suit was made of linseed oil fabric

IMPERVIOUS OVERALL SUIT FOR
PROTECTION AGAINST HS.

Front View.

COATED GLOVES FOR PROTECTION AGAINST MUSTARD GAS

and at the request of the Gas Defense Division this group at once undertook the manufacturing development of this order. A linseed oil fabric was developed having nearly twice the time protection against mustard gas afforded by the French suit, while in place of the same material for gloves there was substituted a pyroxalin coated fabric produced under the direction of Lieut. Abraham. This method of forming the glove was superior to the French, - first because the glove could be sewed up from the original fabric much more readily than from impregnated fabric and, second, because the coating after sewing effectively filled all needle holes and seams, and third, the pyroxalin coating was much superior to linseed oil in initial protection and in service period.

At the time of the signing of the armistice, the work of coating the fabric for the suits and manufacturing and impregnating the gloves was in charge of various members of this division working under the direction of Lieut. Abraham. Sufficient fabric had not yet been accumulated to put the suits into large scale production.

Navy Facepieces and Canisters. Inasmuch as practically all the various types of navy masks upon which work was undertaken had the canister more or less integral with the facepiece, the canister and facepiece will be reported as a unit.

The work at this Station on gas masks for the navy was initiated in November 1917, as a continuation of the work which Lieut. Commander A.H. Marks had begun toward developing

EARLY TYPE OF NAVY MASK

Contains nose clips and mouthpiece.

a Snout type mask.

The details in the construction of this mask were carefully worked out and specifications prepared for the navy. Production was started immediately and a large number of these masks manufactured.

In its final form the mask embodied principles taken from each of the three best masks in use at that time: English, French, and German. In external appearance, weight, and arrangement of head harness, the mask resembled the earlie German masks which were constructed of rubberized fabric. The flutter valve, mouthpiece, and noseclip are of American pattern, similar to the English design. The canister and check valve are similar to the French A.R.S.

Shoulder Carrier Mask. About the same time that the Snout type mask was put into production, the Mechanical Section began the development of a mask for naval officers. The facepiece of this mask was almost identical to that developed about the same time for the army Tissot mask, the distinctive feature being a die casting with the inlet tube at right angles to the flutter valve, allowing the flexible tube to be carried back over the shoulder to the canister which was suspended by a rope harness on the back. The facepiece is composed of pure rubber protected by an additional layer of tough black stock to prevent cuts or punctures. The eyepiece frames are moulded from the same black rubber. The mask is

cured on an aluminum form without wrapping.

In assembling the mask, the eyepiece lenses are held in place by frames with lugs which are bent up under a washer so as to press the rubber tightly against the glass.

The inhaled air is distributed to the lenses by Y-shaped rubber clarifying tubes. The chin rest is made of rather soft rubber with horns which fit on either side of the chin to hold the mask in place. The head harness is made of two rubber bands about one inch wide passing around the head connected to the top of the mask by a non-extensible rubberized fabric strap.

About one hundred of these masks were made and submitted to the navy for test, but this type was never officially adopted.

Head Canister Mask. During February and March 1918, a mask was developed by the Mechanical Section to carry the canister in back of the head.

The facepiece of this mask is of the general Tissot type, but embodies several novel features. The inhalation tube extends around the left side of the head and is attached to the facepiece over the eye. It terminates in a flat "diffusing tube" of semi-circular profile which extends down between the eyepieces covering an oblong opening through the facepiece. The incoming air is distributed to both lenses by means of a baffle made of a thin strip of rubber. The

HEAD CANISTER AND MASK

exhalation tube consists of a brass tube bent sharply upward so that the flutter valve is inverted and stands parallel to the center of the facepiece, the upper end just below the center of the eyepieces. The head harness is attached to a hood of open mesh fabric which fits over the head and supports the canister in a horizontal position at the back of the head and neck.

This mask was submitted, together with the shoulder carrier, type described above, to the navy, but rejected in favor of a mask designed by Lieut. Squiers of the navy and Mr. Coe of the U.S. Rubber Company which carried the canister directly on top of the head.

Helmet Canister Mask. In June 1918, we were requested by Lieut. Squiers to cooperate in improving the head type mask with special reference to facepiece design and the development of a smoke filter.

The facepiece of this mask is constructed of red, non-blooming rubber, covered with olive drab stockinette. A hood of the same material covers the head and is reinforced by a single elastic tape extended around the head through loops in back of the hood. A felt lined aluminum helmet, on which the canister rests, is attached to the hood by three elastic tapes.

To the forward end of the canister is attached a Y-shaped aluminum casting. A rubber inhalation tube is attached to each

EARLY TYPE OF NAVY HEAD MASK WITH FELT FILTER
AND WATERPROOF COVER.

A COMPLETE NAVY HEAD MASK

WITHOUT SMOKE FILTER.

of these outlets and conducts the inhaled air into the eyepiece wall.

The exhalation tube, upon which the flutter valve is seated, is formed from rubber as part of the facepiece and extends upward between the eyepieces. A rubber dam separates the eyepiece chamber from the lower part of the mask. Moist air is prevented from getting up to the eyepieces by small flutter valves seated on metal frames in the dam. The facepiece and hood are cured on a flat form cast of aluminum. The eyepiece forms and the rods extending upward from them to serve as cores for the inhalation tubes are part of the form.

The work of this Station on this facepiece has been an attempt to increase the comfort and efficiency of the mask. The comfort of the mask has been increased by bringing the inhalation tubes in at the side of the eyepieces instead of the top, thus relieving the pressure on the eyebrows.

The dam with which the mask was equipped gave a great deal of pressure on the bridge of the nose while the small flutter valves raised the resistance to inhalation greatly. A more comfortable dam known as the Miller type was substituted and the snail shaped ventilating tubes which have proved successful in preventing dimming in the army masks were substituted for the valves. In order to make these tubes effective, it was necessary to develop a small mica disc check valve

to fit in the intake end of the canister.

The binocular vision has been improved by decreasing th distance between the eyepieces. This was accomplished by making the facepiece form and the core of the exhalation tube as thin as possible between the eyes, and moving the eyepiece forms up to the edge of the form. A detachable flat felt filter outfit for this equipment was also developed by this section. This consists of two of the rectangular felt filter pads enclosed in their waterproof jackets, containing a total of about 60 sq. in. area, which was attached by straps to either side of the helmet, the air connection being through a quick detachable Y at the back of the canister.

Navy Submarine Canister. Another minor development carried on for the navy was the development of an emergency canister which could be used with various types of packing. This is a canister similar in general appearance to the canister on the German mask, equipped with a special mouthpiece and nose-clip, but without a facepiece. It is contained in a box approximately 3½" in diameter and 3" high, and for use over short periods is a very satisfactory emergency outfit.

MISCELLANEOUS DEFENSE PROBLEMS.

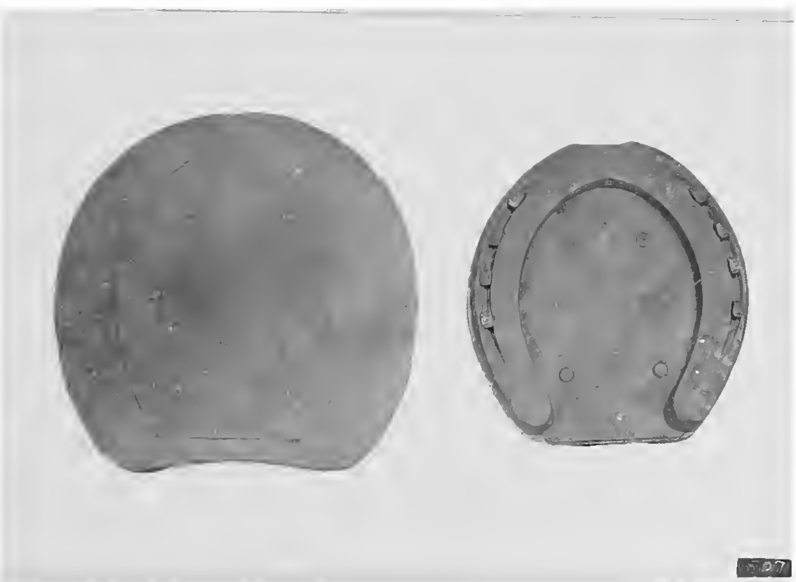
Horse Masks. The original work on the horse mask was started late in 1917, and consisted in the main of the development and manufacturing methods for a mask modeled along the lines of the British horse mask brought to this country by Capt.Dudley.

NAVY SUBMARINE CANISTER

NAVY SUBMARINE CANISTER.

This mask was put into production by the Gas Defense Division late in the spring of 1918. Certain defects, mainly in the matter of breathing resistance which developed in field tests of this mask, together with a new type of fabric impregnation worked out by the Chemical Development Section, led to a reopening of this problem early in the summer. As a result of the cooperation between the Chemical Development Section, the Development Section of the Gas Defense Division, and the members of this section, a new type of horse mask was designed and production details worked out. This mask was a very radical improvement over the early American and British masks in that its breathing resistance was reduced to practically nothing. A new type of harness was also worked out which allowed the mask to be put on and off entirely independent of any bridle or halter which the horse might be wearing. At the time of the signing of the armistice, the horse mask factory of the Gas Defense Division had the material on hand and the plans worked out for an extremely large production of masks of this type.

Protection of Horses' Feet. Early in the spring of 1918, request came from the chemical laboratory of the A.E.F. for the protection of horses' hoofs and ankles against mustard gas. A very satisfactory solution of this problem was worked out, consisting first of a steel and fabric pad for application between the shoe and the hoof and, second, a boot or gaiter covering the entire lower limb from the knee to the



IMPERVIOUS BOOTS AND PADS TO PROTECT HORSES' LEGS AND HOOFS AGAINST HS.

shoe which is made of a heavy grade of duck coated on both sides with pyroxalin. The only exposed portion of the leg below the knee was the slight cavity at the back of the foot between the pad and the frog which was filled with an absorbent packing of tar and oakum which was to be removed immediately after a horse came out from an area where mustard gas was present. Acknowledgement should be made in connection with this work of the substantial assistance rendered by Mr. William J. Kent of the United States Rubber Company, who during the course of this development extending over a period of several months devoted the majority of his time to work along this line. This work was reported by Dr. W.K. Lewis to the A.E.F., but as the end of the war came shortly after this, nothing was done further on this problem.

Trench Fans and Sprayers. During the winter of 1917-18, designs for both trench fans and trench sprayers for removing the gas from trenches were worked out by this Division along lines and models submitted by Major Auld and Captain Dudley of the British Anti-Gas Service. These were put into experimental production and specifications on them turned over to the Gas Defense Division.

Adaption of Telephone to Gas Mask. A large amount of work was carried on in this section in testing out and refining the relative merits of a large number of devices which had been worked out in connection with the adaption of the telephone to the gas mask. In this investigation, very valuable cooperation from the Western Electric Company, the Stromberg Carlson

Company, and the Holtzer Cabot Electric Company, manufacturer of telephone equipment. Telephone transmitters were tried out at all points of the mask from the facepiece to the top of the canister. Our final recommendation in this connection was that the transmitter be attached to a "T" located in the flexible hose about 3 inches above the top of the canister.

Aviators' Masks. Early in 1918, a member of this staff was detailed to work with Dr. Eyster of the University of Wisconsin, who was acting as consultant with the Aviation Board in connection with the development of a mask for feeding oxygen to aviators at high altitudes. This work was relatively unsatisfactory on account of the constant change in specifications to be met. In the summer of 1918, however, when this work was taken over by the Aircraft Production, our work in this connection was again renewed at the request of Capt. Hults, and a man detailed to work exclusively on this problem. As a result of this work, several very satisfactory models were developed and the work is being carried on at the present time by the Aircraft Production Board who have taken over all of the models and special tools which were developed in this connection.

OFFENSE PROBLEMS

Mobile Toxic Gas Cylinder. Work on this problem was first started by the former Mechanical Section under Mr. H.H. Clark on request of Mr. G.A. Burrell for a mobile unit that would

AVIATORS' OXYGEN MASK

Type V.

Goggle type, eyepieces extended.

AVIATORS' OXYGEN MASK

Type VI.

replace the emplacement cylinders that had been previously used for toxic gas cloud attacks. These latter were difficult to put in position without protection, and since a long time was taken to properly place them, their use was very uncertain, since favorable weather conditions had to be waited for in addition to the time taken to place them in position. Another defect of the emplacement apparatus was the nozzle which gave an excessive amount of noise, and gave warning of the attack. The work of this section comprised the development of a suitable cylinder for the gas, stop valve to close the cylinder during charging and after discharge, and to protect the opening valve, and the opening valve itself that was used when the tank was fired. A suitable nozzle was also developed to decrease the noise of discharge. Recommendation of this section was for a light tank about 8" in diameter, 16" long, and this was adopted and specifications drawn up by the Ordnance Department. The work done on the stop valve was in the form of cooperation with members of a valve committee from the Pyrotechnic Section and the Ordnance Department. A satisfactory valve of the semi-needle type with forged bronze body and Monel metal stem was finally produced. This valve was put in production by the Ordnance Department. A special type of stop valve with a hollow stem was developed by this department and recommendations were secured for further development from the Ordnance Department. A number of opening

TYPE NO. 2 FABRIC NOZZLE - NOTCHED NUB, CAST IRON OPENING VALVE - FUSE FIRING DEVICE.

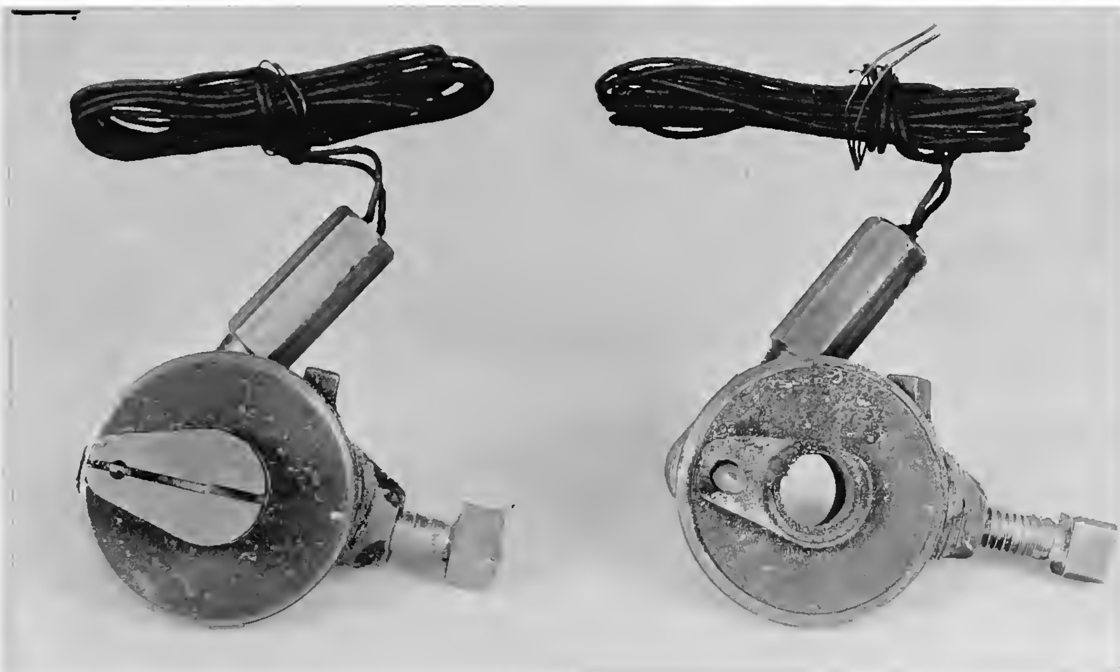
valves were developed, the final one being in the form of the Crown Cork and Seal Company bottle cap, using a lead gasket backed up by cork. This seemed to promise favorably at first, but later developed defects that caused its rejection. The work on the discharge nozzle resulted in the production of one using a diaphragm of special cotton fabric which gave good atomization of the phosgene-chlorine mixture used in the toxic gas cylinders and a high rate of discharge with small size and weight. Its single defect was the possibility of corrosion by the toxic gases. Impregnation experiments were started to overcome this objection, but were not completed at the time of cessation of work at the University. Experimental tests showed the nozzle to be satisfactory regarding corrosion during discharge, so it would only be necessary to protect it during storage and transit.

When the work of the Mechanical Section was taken over by the Mechanical Research and Development Section, a number of the above problems remained uncompleted, and a vigorous attempt was made to eliminate them or to develop them to a successful conclusion. The bottle cap opening valve did not survive a rather severe series of tests made by the Pyrotechnic Section, tests that, however, the valve put into production would without doubt also have failed under. It was not possible in the time that elapsed before experimental work at the University was closed to develop the fabric nozzle completely, but an entirely new type of opening valve was

TYPE NO. 2 FABRIC NOZZLE - NOTCHED NUB, CAST IRON OPENING VALVE - ELECTRIC FIRING SQUIB.

successfully developed. This was in the form of a nub of cast iron forming part of the valve casing. This was grooved and had two arms projecting from it so that the nub could be burst apart by the action of a small pointed plunger impelled by a light powder charge. The powder charge could either be ignited by a blasting squibb or by a time fuse. This type of valve operates instantaneously as compared to those utilizing a melting outcompound that is variable in its results. No noise is made but a slight metallic click when the nub is ruptured. It is also absolutely tight and there is no chance for leakage to develop. Since the grooves cut in the nub expose the metal, this can be carefully examined and tested for leakage. If there are any defects, they will show at once and, if not, it can be assumed that the valve will remain absolutely tight. Tests of this valve were made at Lakehurst, N.J., and at the University. They appeared very satisfactory and encouraging to the Trench Warfare Section of the Ordnance Department, having the toxic gas cylinder in hand and this Division requested that full details and specifications be provided them so the valve could be further developed.

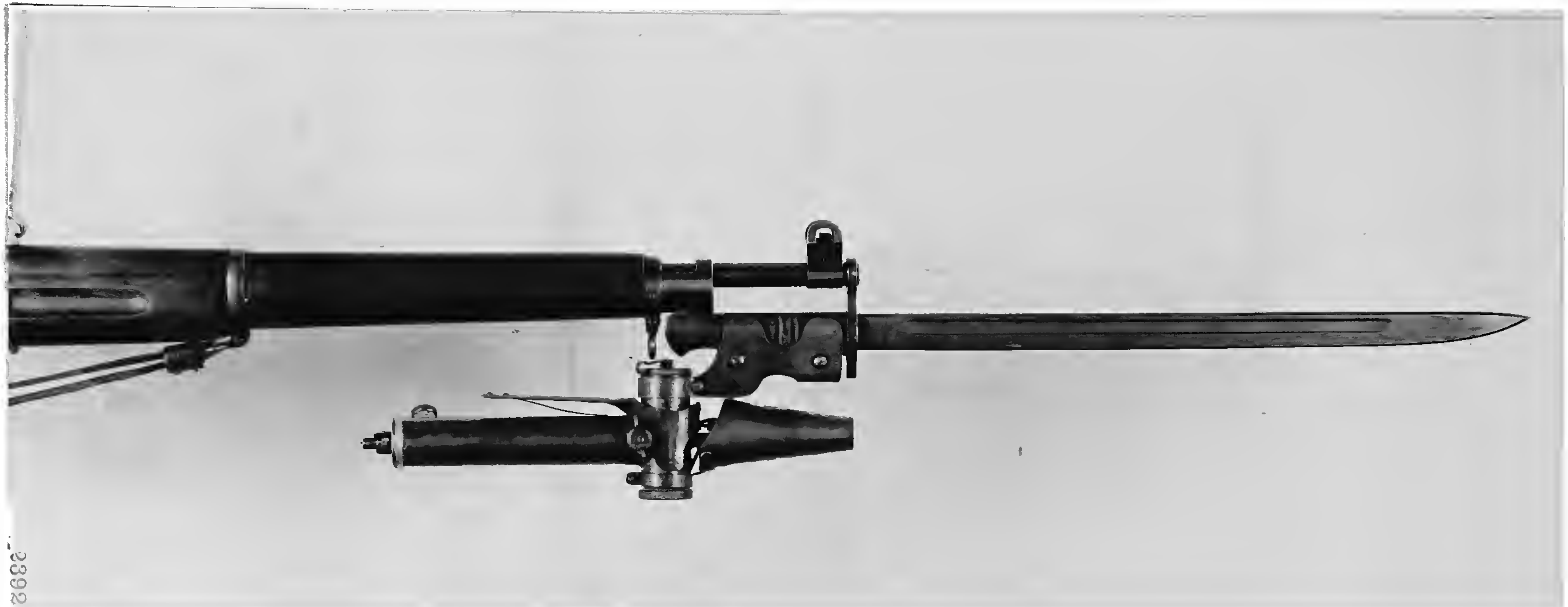
<u>Flaming Bayonet</u>. This problem originally came to the former Mechanical Section of the University from the Pyrotechnic Section, and was taken over by this section together with other work during a period of re-organization. The original suggestion of the device had apparently come from Lieut. Ball



EXPLOSIVE VALVE

FOR MOBILE GAS ATTACK CYLINDER

and Lieut. Patch of the Trench Warfare Division of the Ordnance Department. The idea was to construct a small flame projector that could be carried on the end of a rifle and which could be used during hand to hand bayonet fighting. The first type comprised a cylinder carrying a piston to force out the flaming liquid, and this was actuated by a spring or by air pressure. A form of pilot light that would be invisible to the enemy was to be provided for igniting the flaming mixture. The work of the Mechanical Section was firs to develop a suitable non-luminous pilot flame, and this was finally secured in a fairly practical form through cooperation with the Justrite Company of Chicago, who adapted one of their flame-proof miner's lamps for the purpose. The flaming liquid used was gasoline or benzene. The problem was in this condition when it was taken over by the Mechanical Research and Development Section. At this time the whole problem was gone over carefully to see that it was being attacked in the right angle. A conference with Major Matthews and Lieut. Ball of the Trench Warfare Division, Ordnance Department developed that it was not essential that a flaming liquid in the ordinary sense should be used. A large flame of gas or liquid preferably from 5 to 10 feet long and 3 feet in diameter would be desirable. Simplification and reduction in weight were very essential factors. The final device completed by the Justrite Company was successfully demonstrated



ACETYLENE PILOT TYPE, ATTACHED TO RIFLE. MODEL DEVELOPED BY JUSTICE MFG. COMPANY.

before members of the Ordnance Department and the Pyrotechnic Section. There was also present Major H.W. Holland, who had had considerable experience abroad training with the English troops in Flanders. He stated that the weight of a device on the end of the gun would offer no practical objection or interference with the use of the bayonet if it could be made to function successfully. He favored the proposal to use separate shots or cartridges rather than a single flash whose duration could be controlled by the operator. Results of this demonstration were encouraging and work was continued actively to attempt the use of compressed liquid gas both as a pilot flame and a means to project the flaming liquid. Mixtures of compressed gas and flaming liquid were also considered. A large amount of carefully taken data and experimental work showed that the production of a satisfactory pilot flame was very difficult, and a much simpler method would be to employ the flash from a cartridge or flare mixture to ignite the flaming liquid. Several forms of apparatus were worked out experimentally, but the closing down of work at the University allowed only one of these to be put in fairly complete form. This last apparatus comprised a small rectangular shaped can that could be fastened to the rifle by an easily detached clip just under the end of the barrel. This can contains six cartridges containing a mixture of kerosene and a liquid gas mostly propane. The

CARTRIDGE TYPE FLAMING BAYONET
ATTACHED TO 1917 MODEL ENFIELD TYPE RIFLE

mixture was ejected from the small elongated cartridge through a nozzle closed by a plug. This plug was designed to be drawn by a piston sliding in an extension of the tube beyond the capsule and flare mixture and gun powder were placed back of the piston to force this out and to ignite the issuing mixture. In the piston was placed a small hand grenade primer to ignite the powder and flare mixture. A light sliding hammer driven forward by a spring and held back by a tape by means of a handle which was worked by cramping the hand between the rifle and the can. On firing of the capsule the plug, plug puller, firing hammer, spring, and a small cap used to close the end of the tube and the box were ejected ahead of the flaming mixture. The assistance of the Justrite Company was obtained in making up five models of the device. A very satisfactory piece of work was done considering the short time available before the closing down of experimental work at the University.

The above described device was carefully tested and shown before members of the Station's staff and later before a committee from the Ordnance Department which included Col. Thummel, Major Minor, Major Dodge, Lieut. Ball, and a number of others. Considerable interest was aroused, and it was thought advisable to show the device before the General Staff who could pass final judgment upon its tactical value. Two demonstrations were arranged at the War College. The

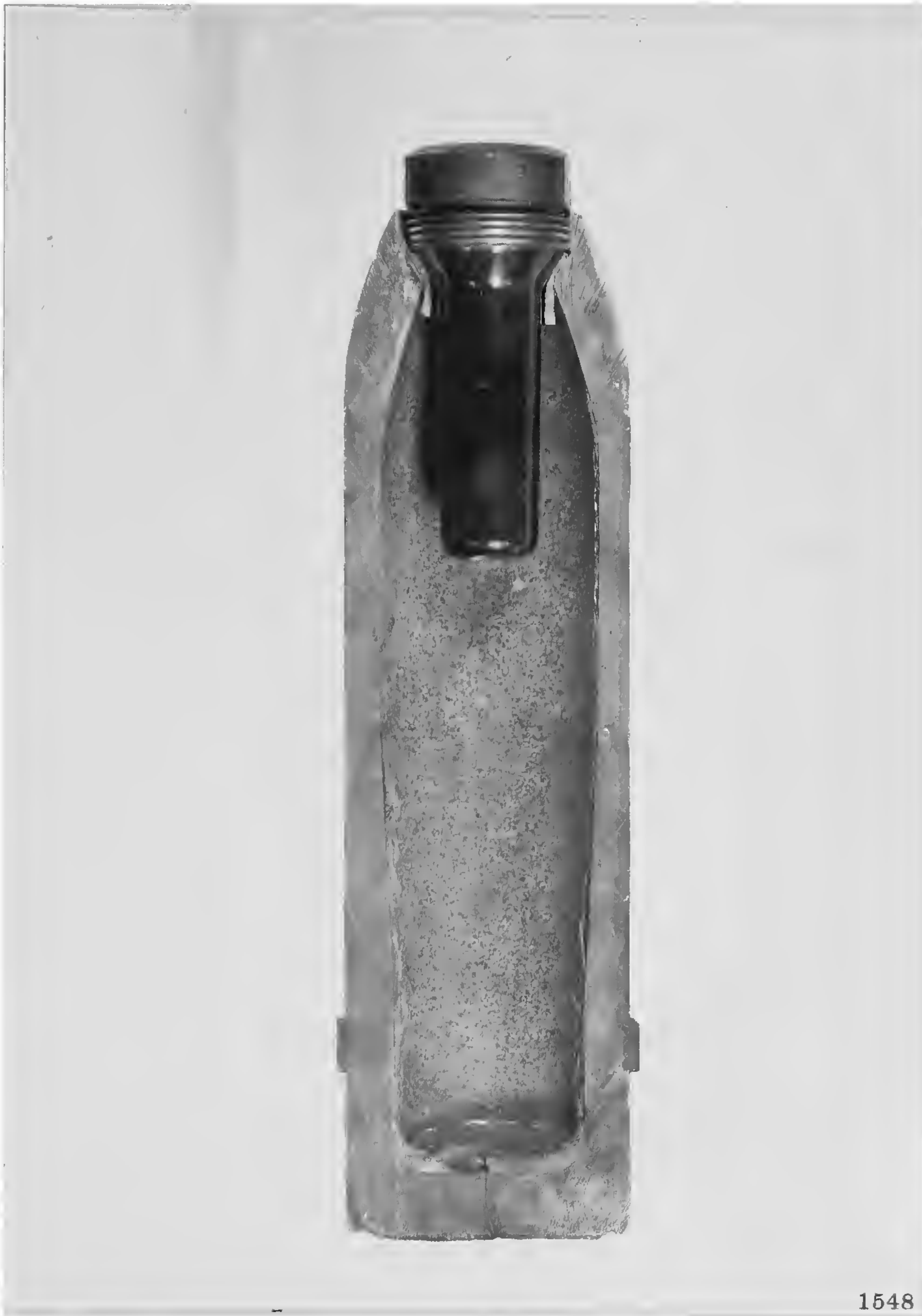
CARTRIDGE PARTS

FLAME SNAPPED AFTER MAXIMUM LENGTH HAD BEEN OBTAINED. FLAME AT POINT OF EXTINCTION.

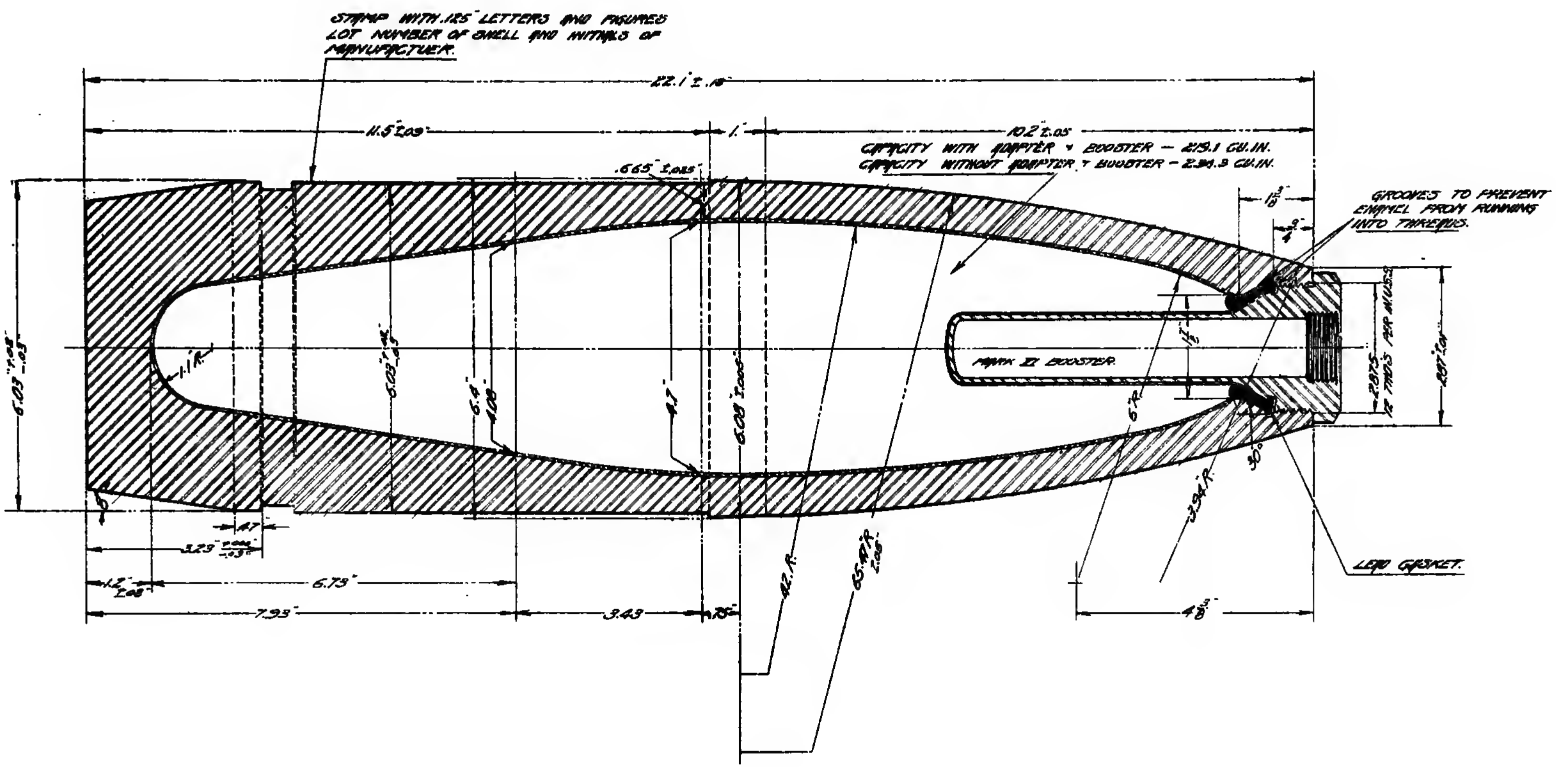
second demonstration, in the nature of a final show before a picked committee of experts, resulted in the recommendation of this device for completion. Steps have been taken to continue this work. It is necessary to develop a more satisfactory flaming mixture, inasmuch as the present combination is somewhat unstable chemically. Other parts must be simplified mechanically, and made more rugged. This work is now in progress, and it is estimated that perhaps six months will be required for its completion, as it will be necessary to finally construct dies in preparation for quantity production.

Seal for Enamel Lined Shell. The request for this development came first from the Pyrotechnic Section, and later the problem developed from the design of the seal alone to that of the design of a shell and booster that would accommodate a satisfactory seal and also the securing of a proper enamel. The work was first started in cooperation with the Pflauder Company to secure a satisfactory enamel. This was secured, but the company required what the Ordnance Department considered an excessive price for further development and further work was done with the Kohler Company which also produced a satisfactory enamel. The work included the design of the 75 m/m 4.7", 155 m/m, 8" and 9.2".

The standard shell, as shown by prints supplied by the Ordnance Department, was generally changed by reducing the



ENAMELED LINED SHELL



WAR DEPARTMENT
AMERICAN UNIVERSITY EXPERIMENT STATION
CHEMICAL WARFARE SERVICE - MECHANICAL SECT.
WASHINGTON D. C.

ENAMEL LINED SHELL
155 M/M – MARK II
FULL SIZE
7-13-18
Drawing No. AI-LII-8
SHEET 1

THE NORRIS PETERS CO., WASH., D. C.

diameter of the neck to give a cell for a gasket. A number of materials were tried, the final selection being one of chemically pure lead. This gasket was approved by both mechanical and chemical sections. Other gaskets that were found suitable mechanically but, due to lack of time not approved by the Pyrotechnic Section follow:

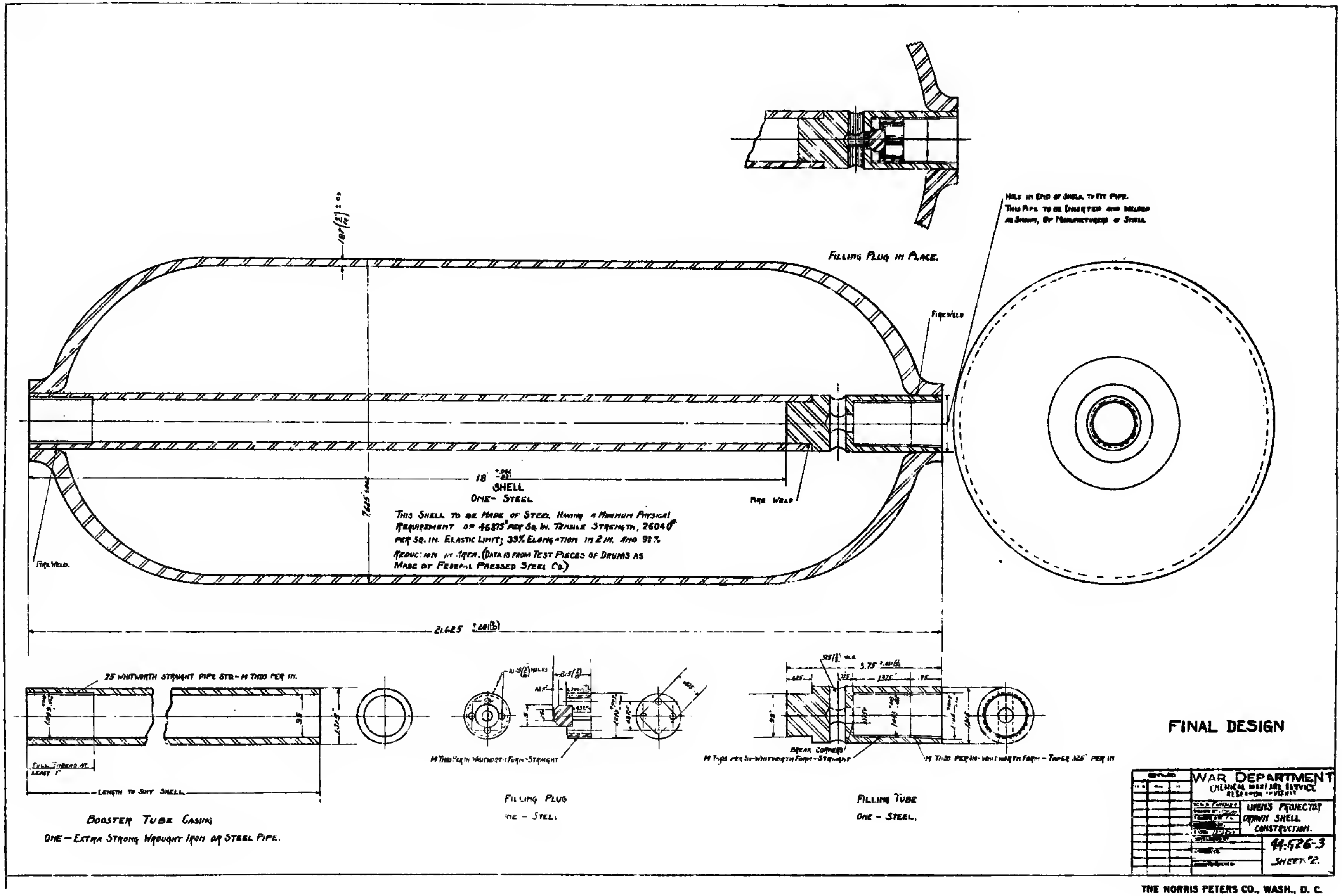
Lead, dipped in sodium silicate, and used wet.

Lead wool, soaked in sodium silicate.

Lead wool, impregnated with glycerine.

Occasional mechanical failures resulting from the use of the dry lead gasket were overcome by the use of these composition gaskets.

Stokes Toxic Smoke Shell. This problem was one of mechanical design to assist the Pyrotechnic Section to develop the standard Stokes shell for use with diphenylchlorarsine. The problem, as outlined by the Pyrotechnic Section was to secure a gas-tight capsule, that could be placed in the shell preferably in filled condition. Openings for discharge would be provided at several places closed by fusible plugs. A smoke mixture similar to that used in the toxic smoke candles would be employed to first melt out the fusible plugs and then vaporize the diphenylchlorarsine. It was important that the diphenylchlorarsine should not become excessively heated so that it would take fire. Two designs were worked out, differing generally in that in one case the toxic material was discharged at the same end as the smoke and in the

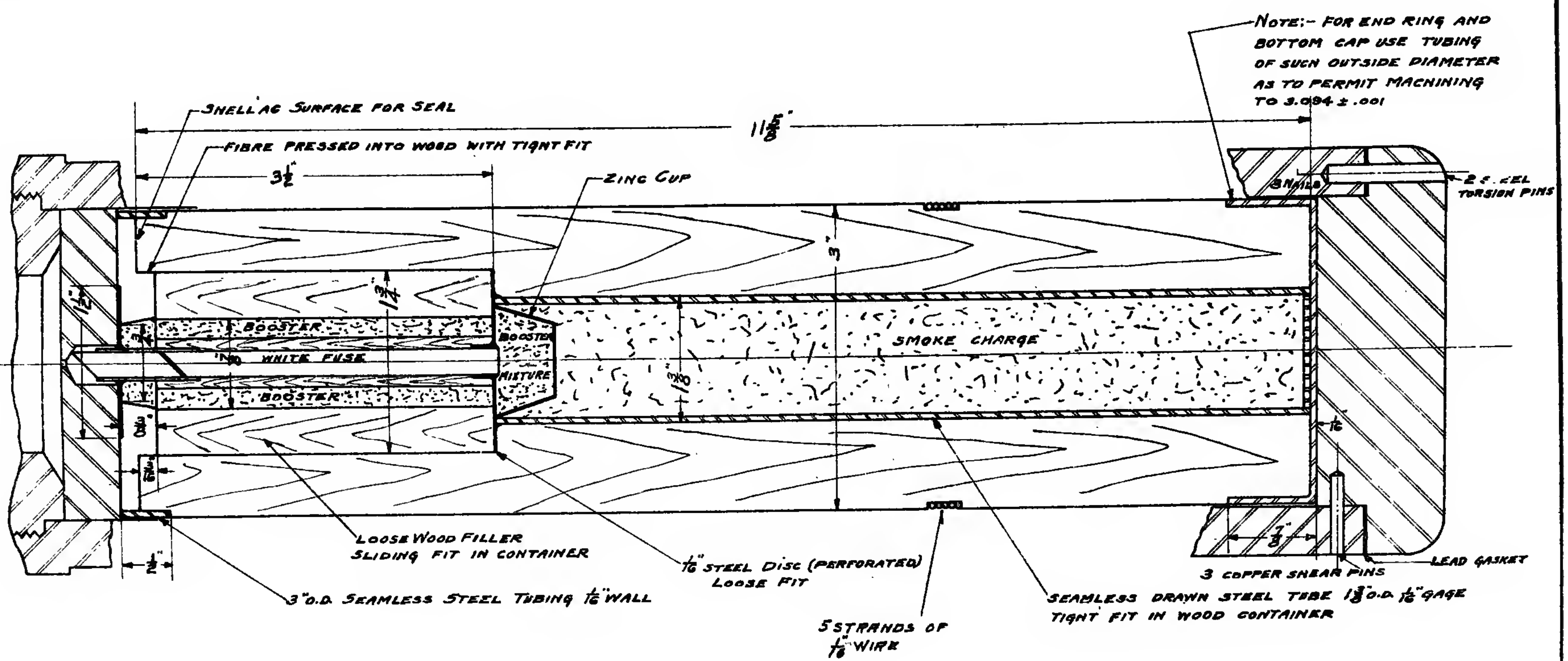


FILLING PLUG IN PLACE.
HOLE IN END OF SHELL TO FIT PIPE. THIS PIPE TO BE INSERTED AND WELDED AS SHOWN, BY MANUFACTURERS OF SHELL.
FIRE WELD
FIRE WELD
FIRE WELD.
18
SHELL
ONE - STEEL
THIS SHELL TO BE MADE OF STEEL HAVING A MINIMUM PHYSICAL REQUIREMENT OF 46875# PER SQ. IN. TENSILE STRENGTH, 26040# PER SQ. IN. ELASTIC LIMIT; 39% ELONGATION IN 2 IN. AND 90% REDUCTION IN AREA. (DATA IS FROM TEST PIECES OF DRUMS AS MADE BY FEDERAL PRESSED STEEL CO.)
21.625
.75 WHITWORTH STRAIGHT PIPE STD. - 14 THDS PER IN.
FULL THREAD AT LEAST 1"
LENGTH TO SUIT SHELL
BOOSTER TUBE CASING
ONE - EXTRA STRONG WROUGHT IRON OR STEEL PIPE.
14 THDS PER IN WHITWORTH FORM - STRAIGHT
FILLING PLUG
ONE - STEEL
3.75
BREAK CORNERS
14 THDS PER IN - WHITWORTH FORM - STRAIGHT
14 THDS PER IN - WHITWORTH FORM - TAPER .125" PER IN
FILLING TUBE
ONE - STEEL.
FINAL DESIGN
WAR DEPARTMENT
CHEMICAL WARFARE SERVICE
LIVENS PROJECTOR
DRAWN SHELL
CONSTRUCTION.
44.626-3
SHEET #2.
THE NORRIS PETERS CO., WASH., D. C.

other case at the opposite end of the shell. Both these types of shell were under construction at the time experimental work was shut down at the University and neither was put in sufficiently finished condition to try out.

Special Livens Shell for Arsine. A request was received for work on this problem by the Pyrotechnic Section, who desired a special shell of the Livens type that would be suitable to contain arsine. The pressure requirements called for a shell of about twice the bursting strength of the standard. Conference with the Ordnance Department developed that the Milwaukee Pressure Steel Company was the most available concern to attempt the manufacture of this shell. A design was made up and a man dispatched to handle the matter with the above concern. They suggested various modifications in the design which would adapt it for their manufacturing facilities. If these were carried out, they stated the shells could be made along with their regular production. The shells were made and after some delay were delivered at the University where they were successfully tried out. A full description is contained in a final report by Mr. W.G. Abbott, Jr.

H.E. Toxic Shell Capsule. This section was requested by the Pyrotechnic Section to develop a container for diphenylchlorarsine to be palced in a H.E. shell into which TNT would be poured in a molten condition. Previous containers had given trouble through leakage. Some attempt was made to develop a



APPROX. WEIGHTS

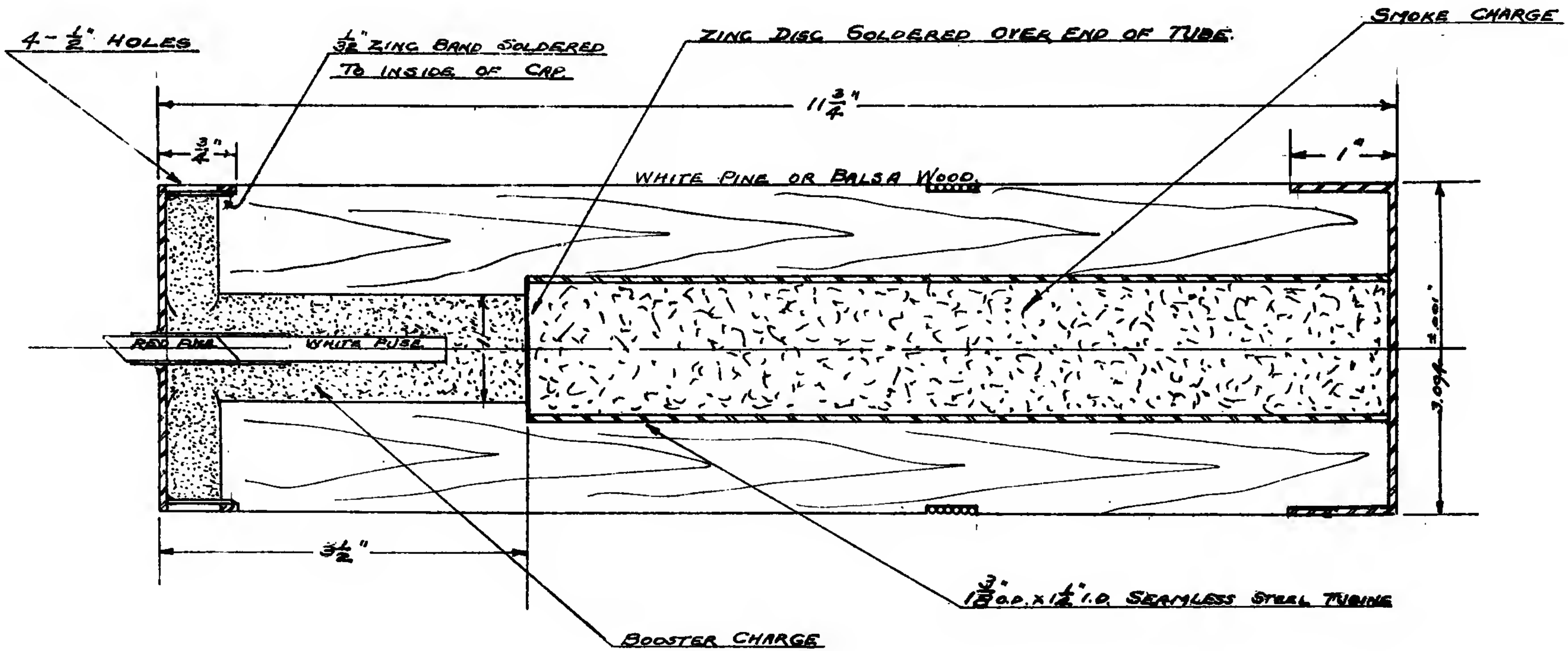
WOOD (.0054)	.40	(BALSA WOOD)
TOP RING / BOTTOM CAP	.34	
FIBRE CAP	.08	
STEEL TUBE	.69	
BOOSTER ETC.	.20	
SMOKE CHARGE	.80	
	2.51	

WAR DEPARTMENT
AMERICAN UNIVERSITY EXPERIMENT STATION
CHEMICAL WARFARE SERVICE - MECHANICAL SECTION
WASHINGTON, D. C.

NAVY MARKER SHELL
DESIGN A

Drawn by	C.H.L.	Scale	FULL SIZE
Traced by	A.H.A.	Date	DEC. 5, 1918
Checked by	[signature]	Revised	
DESIGNED BY	[signature]	Revised	
Approved		Approved	

Drawing No. 1603
PROB. 48



WAR DEPARTMENT AMERICAN UNIVERSITY EXPERIMENT STATION CHEMICAL WARFARE SERVICE - MECHANICAL SECTION WASHINGTON, D. C.				
SMOKE CONTAINER FOR NAVY MARKER SHELL				
Drawn by	C.H.L.	Scale		Drawing No.
Traced by	C.H.L.	Date		
Checked by		Revised		48-1605-3
DESIGNED BY	C.H.L.	Revised		
Approved		Approved		

THE NORRIS PETERS CO., WASH., D. C.

container of pressed steel, but this appeared too strong to be ruptured with certainty. A recommendation was made, therefore, that glass or stoneware containers be experimented with before deciding as had been done that they could not be made satisfactory. This recommendation was followed and concluded the work of this section.

Delayed Time Fuse. This problem was one to test out a device for the Pyrotechnic Section that had been developed by the Mechanical Section, who did not have proper testing facilities. It was found too irregular in action to be satisfactory and this section was asked to propose a design on different principles. The work was about to be started at the time experimental development was shut down at the University.

PYROTECHNIC SIGNAL PROBLEMS.

4" Navy Marker Shell. This problem was one of mechanical design, assistance having been requested by the Pyrotechnic Section in this part of the development which had not kept up with the pyrotechnic development. Mr. C.H. Leckberg was especially assigned to assist the Pyrotechnic Section, and developed several designs that embodied the essential principles for successful operation.

The problem was to secure a float light that could be ejected from a shell on striking the surface of the water, The light was to be ignited at the moment of ejection and

would burn giving off a dense brown smoke. Troubles were experienced with the container breaking either during the firing from the gun or at the time of ejection. Considerable difficulty had also developed with the ignition. A further difficulty arose when the first shells were fired from the naval gun. These fell short and showed that they tumbled during flight.

At the time of completing experimental work at the University, the development on the problem had progressed to where the shells could be fired from a Stokes mortar and the float light ejected without damage, and functioning as to ignition. A number of tests of shells fired statically under water demonstrated that the ignition under these conditions would be satisfactory. While the problem was not completed, and final tests have not been made of the shells fired from the regular 4" naval gun, the work had been pushed as far as was possible at the time of shutting down of all experimental work.

Airplane Signalling. This problem was taken up at the request of the Pyrotechnic Section to assist in putting into mechanical shape a float light that could be thrown from an airplane, to give a marker for landing on water in darkness. The development required a container of a pyrotechnic that would float on the water in a stable condition, and ignition means for the pyrotechnic, and a parachute or other means to

AIRPLANE FLOAT LIGHT

guide it during its flight through the air. Two types were tried out, and one of these found satisfactory on all the points required. The only difficulties encountered in the whole development were with ignition, and these caused the Navy Department to abandon the development for a time and consider a float light proposed by a Pyrotechnic concern. This latter, however, did not prove successful and work was again started with the Pyrotechnic Section to allow them to perfect suitable ignition means for the flare mixture. This work had not been completed when experimental development was stopped at the University.

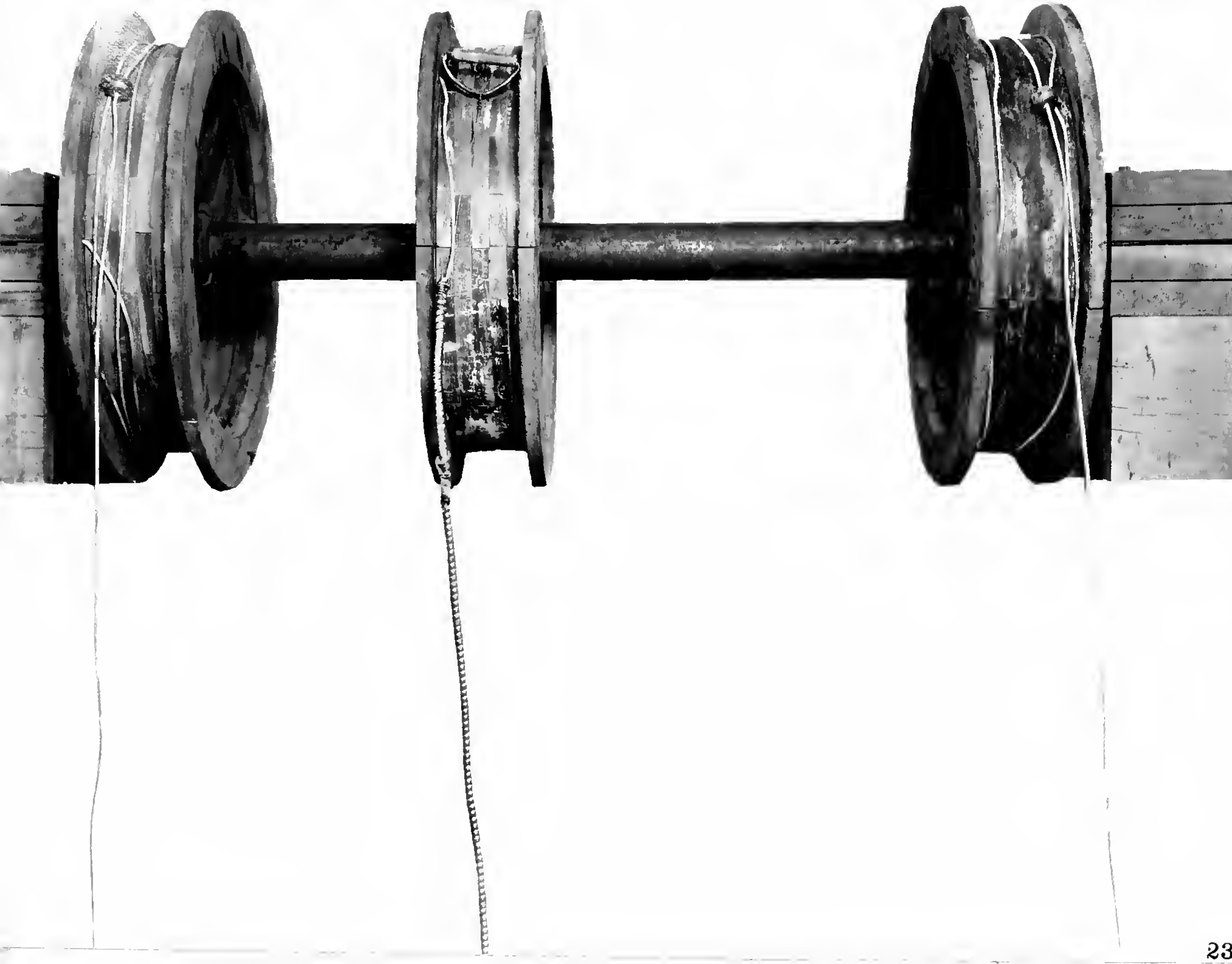
Catapult for Experimenting with Airplane Signals. This apparatus was designed and built on account of the difficulty in being able to secure an airplane at all times from which to make experiments. The catapult, as constructed, was capable of ejecting the landing signals being experimented with at a velocity approximating that of an airplane in flight. The action of the signal in flight and on landing could therefore be studied in detail. The apparatus was set up after constructing the roof of the unfinished laboratory building at the University, and was successfully used in firing the signals during their experimental development.

Submarine Recognition Signal. This problem came to the former Mechanical Section of the University both from the Pyrotechnic Section and from the Navy Department. The problem was first considered one of pyrotechnics, but later when

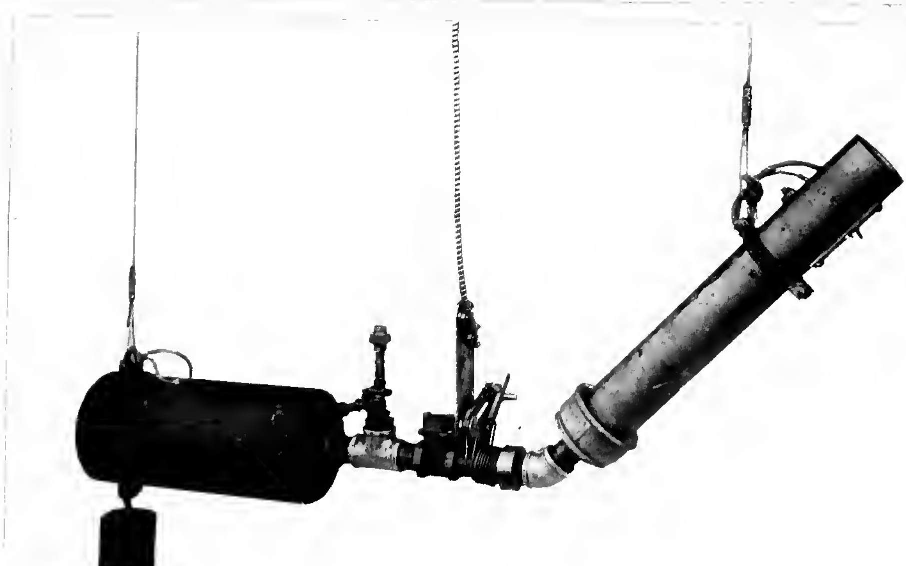
CATAPULT DESIGNED TO THROW AIRPLANE
SIGNALS AS NEAR ACTUAL AIRPLANE CON-
DITIONS AS POSSIBLE.

the work was taken over by the Mechanical Research and Development Section the problem had developed into one of mechanical design and experiment with the pyrotechnic part practically complete and of secondary importance. The problem was for a signal that could be discharged from a submarine when submerged when under way, that would show its presence to friendly vessels at the surface by means of a coded signal. This signal was developed in the form of a pyrotechnic bomb showing colored lights at night and colored smokes in the day time. The first development was of the 4" diameter signal. This was made of the so-called pressure firing type in which a diaphragm fired the bomb by means of the change of pressure on coming to the surface. The demand for this signal was very insistent and the final design was tried out in a tube built into a submarine without the opportunity to eliminate minor defects by preliminary experiment. The signals built and tested all came to the surface, but did not function. The only one recovered showed that the mechanism had functioned, but leakage had wet the powder and caused it to fail to fire. At this stage in the development the problem was taken over by the Mechanical Research and Development Section, and occasion taken to reconsider the whole design, since the navy thought that a smaller signal would be desirable. Two possibilities were considered, one in which the signal was fired by a time fuse ignited at the moment of discharge that would give the signal sufficient time to rise to the surface,

COMPLETED SIGNALS BROUGHT BACK FROM TEST OF JAN. 2,1919.
DUMMY, TYPE NO.8 AND TYPE NO. 5.



2381



2382

TESTING APPARATUS REQUIRING NO SUBMARINE

and the other some form of pressure firing device. The fuse type appeared easiest to construct and at the suggestion of the Navy Department development was started first on this one. Two designs were made up, and every part of the apparatus tested out carefully at various stages of development. The work finally culminated in the firing of the signals through an experimental air gun that was lowered 50 ft. under water. All the five signals functioned perfectly, and the remainder of the 10 signals that had been constructed were held for samples and further test. Some preliminary designs were made up of the pressure firing type of signal and embodied in a final report for the assistance of those continuing the development.

Fuse Testing. This investigation was undertaken particularly in connection with submarine recognition signal and also because very little data existed on the effects of pressure generated in inclosed space on the burning rate of fuses. Three varieties of standard fuse were burned in varying lengths and in different volumes and the pressure and temperature conditions carefully noted and plotted. For the particular problem under investigation it was shown that the burning rate of the fuse did not vary appreciably enough to affect its operation when confined in the submarine recognition signal. The work was laid out under the direction of Lieut. H.W. Asire and covered in a final report by S.S. Amdurskey on Fuse Testing.